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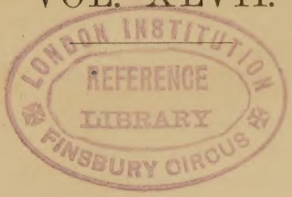

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLVII. NOVEMBER 12, 1886. No. 1

J. W. L. GLAISHER, M.A., F.R.S., President, in the Chair.

Maurice Loewy, the Observatory, Paris; and
G. Spörer, Astrophysical Observatory, Potsdam,

were balloted for and duly elected Associates of the Society.

A Reply to Mr. Neison's Strictures on Delaunay's Method of Determining the Planetary Perturbations of the Moon. By G. W. Hill.

For several years past Mr. Neison has been maintaining in the *Monthly Notices* and *Memoirs* of the Society that Delaunay's investigation of the two long period inequalities in the Moon's motion arising from the action of *Venus* is seriously defective, on account of the omission by him of a certain class of terms. In the *Monthly Notices* for last June there appears a long article by him upholding this view; to this I wish more especially to direct attention.

At the outset I may be allowed to say that all this criticism is without foundation. It appears to arise, partly from the very confused conception Mr. Neison seems to have of the nature of Delaunay's method, and partly because he fails to notice that Delaunay, after setting the degree of approximation he wishes to attain, always rigorously adheres to it. If we were obliged to admit the validity of *all* the statements in this article, an easy corollary from them would be that Lagrange's general method of the variation of arbitrary constants in the problems of mechanics was a blunder. Now, I think that no one acquainted with this method could, for a moment even, entertain such a

proposition. Hence we may conclude there is some flaw in the reasoning of this Paper. But this must be substantiated by noticing *seriatim* the objectionable points.

In the first place, why bring forward Hansen's published values of the coefficients of these inequalities for the purpose of throwing discredit upon Delaunay's values, when their author, himself, virtually confesses he has no confidence in them, by saying he had computed them in two different ways, and found essentially different results? And, to the very end of his life, he appears never to have been able to find out whether one of these results was right, and which it was, or whether both were wrong. It would be an amusing circumstance should it turn out that the set of values, withheld from publication by Hansen, were identical with those of Delaunay.

There is some inexactitude in Mr. Neison's statement, regarding the degree of approximation adopted by Delaunay in calculating the coefficient whose argument is $8l'' - 13l'$. In this connection we note that, on account of the close proximity of the Moon to the Earth, a planet cannot produce in her motion inequalities of the same order with those it produces in the Earth, but that they are only of the order of these multiplied by the solar disturbing force; and this is as true of the indirect action as of the direct. Now, on referring to Delaunay's work, we see that he has considered, not only the term of the lowest order in each portion of the coefficient, but also multiples of this by m^2. Hence, it is correct to say that he has considered terms of the order of the mass of *Venus* multiplied by the square of the solar disturbing force, but not those multiplied by the cube of the latter.

Mr. Neison regards the evidence adduced in his earliest Paper, as conclusively establishing the omission by Delaunay of a certain class of terms. But what was this evidence? Simply, that Hansen was at variance with Delaunay. Now, since Hansen was as much at variance with himself as he was with Delaunay, what weight ought to be attributed to this evidence? Then, Mr. Neison believes that certain discrepancies between results, obtained on the one hand by himself, and, on the other, by M. Gogou and myself, have their origin in the same cause. Now, if Hansen's investigation and also Mr. Neison's were accessible, this point could be immediately pronounced upon; but since they are not, it appears useless to speculate on the matter.

Mr. Neison says (p. 416), "He (Delaunay) substitutes the preceding value for the term in the disturbing function with the argument ζ in the differential equation and integrates." This does not correctly represent what Delaunay does. For he substitutes in the differential equation not only the term factored by $\cos\zeta$, but also the non-periodic portion of R: to wit, in the memoir of 1862, the terms

$$\frac{\mu}{2a} + m' \frac{a^2}{a'^3}\left[\frac{1}{4} + \frac{3}{8}e^2 + \frac{225}{64}e^2\frac{n'}{n} - \left(\frac{31}{32} - \frac{97}{32}e^2\right)\frac{n'^2}{n^2}\right],$$

and, in the memoir of 1863, the terms

$$\frac{\mu}{2a} + m'\frac{a^2}{a'^3}\left[\frac{1}{4} - \frac{3}{2}\gamma^2 + \frac{3}{8}e^2 + \frac{3}{8}e'^2\right].$$

The terms differ in the two cases, because the degree of approximation aimed at requires the preservation of different terms with allowable neglect of all the rest. From this non-periodic portion of R results, in both cases, much the larger part of the two inequalities considered. Mr. Neison's failure to note this completely invalidates his argument on the two following pages, by which he attempts to prove the incompleteness of Delaunay's procedure. And, in this connection, it may be noted that it is not necessary that the coefficient in (38) should vanish identically in order to prove Delaunay right; it is necessary only that it should turn out of such an order of smallness as to prove that the adopted degree of approximation had been attained.

On p. 417 it is said that the coefficients B and B′ "only differ by small quantities, unimportant for the present purpose." So far from this being the case, the difference B′ − B constitutes one portion of the terms which Mr. Neison, all along, has been asserting were neglected by Delaunay.

That Delaunay, in treating the two *Venus* inequalities, discarded his own method, and employed the old one recommended by Poisson, is erroneously stated on p. 423. The fact is that the method followed is the same as that he had used in deriving the solar perturbations. Next, Delaunay is found fault with (p. 424) because he confines himself to calculating in R the term which has the argument of the particular inequality he is dealing with; while it is plain that there are a multitude of terms in R, having other arguments, which could contribute to the value of the coefficient sought. This is true, but Delaunay's reasons for passing by these terms are quite evident. In the first place, it must be remembered that his final expression for the inequality is a formula of substitution, which must be made, not only in the mean longitude of the Moon, but also in the equation of the centre, in the evection, variation, and in all the inequalities arising from solar action. Hence, Delaunay's method of treatment enables him to obtain, with very little additional labour, all the terms in the expression for the *true* longitude which involve the very small divisor arising from the slow motion of the argument which he is considering; and that whatever may be their arguments. And, secondly, while the terms in R, having other arguments, which would be treated by Delaunay as giving rise each to a distinct transformation, can, in a strict sense, add something to the coefficient of the inequality in the *true* longitude, practically these terms are insensible; for, although they may be of the same order, before integration, as the quantities retained, they are altogether independent of the excessively small divisor which arises from the slow motion of

the argument of the inequality. As illustrating this point, it may be remarked that, in the case of the two *Venus* inequalities in question, we get such relatively large coefficients as 16″ and 0″·27 only by multiplying the corresponding terms in R by factors which are about 15,000,000 in the first, and 10,000,000 in the second inequality. Hence, if there are other terms, which rigorously ought to be added to the preceding values, but which, while in other respects of the same order of smallness, have factors not much exceeding unity, it is very apparent they may be neglected.

In the next place we find Delaunay charged with neglecting every term of the solar perturbations save the term of the lowest order in the variation in calculating the proper form for R. And it is said that his development "in no sense depends on his method of transformed elements, though made to appear as if it does; nor does it differ in any way from the values hitherto employed by astronomers save in being somewhat less complete." These statements misrepresent Delaunay. He arranges under four different heads the transformations made by him, and they involve no less than 16 out of the 57 operations of his first volume, besides 4 complementary ones. And whether the amount of work in this be regarded as much or little, I have ascertained that it is precisely sufficient to obtain the degree of approximation he proposes in the coefficients B, viz., to terms involving m^2. Carrying the approximation farther could only have afforded him terms of a higher order. It is, of course, open to Mr. Neison to say he deems this degree of approximation insufficient; and nothing can be said in opposition. But this is very different from saying Delaunay has committed errors. Again, I am not aware of the existence of any published investigation in which the degree of approximation is greater.

The reasoning Mr. Neison employs to show that Delaunay deserts, in this investigation, his own method and returns to the old method recommended by Poisson, is certainly very strange. He notes that the differential equation used has nothing in it to distinguish it from the corresponding one which Poisson would have used. But from what circumstance does this state of things arise? Simply because it is Delaunay's habit to omit, in the statement of his equations, every term which gives rise, in the final result, only to terms of a higher order than he has agreed to retain. The factors in question, in Delaunay's method, can be expressed only as infinite series; it is necessary, therefore, to cut them off at some point, and he determines this point in the way just stated. If reference is made to the same equation, in the memoir where Delaunay treats the other *Venus* inequality, it will be found to be duly distinguished by the presence of additional terms, Delaunay writing as many as are just sufficient for his purpose.

Mr. Neison next notices two assumptions, which he says have been made by Delaunay in his integration.

The first is that the factor $\frac{2}{an}$, which multiplies $\frac{dR}{dt}$, is treated as if it were constant. But here he forgets that, with Delaunay, at this stage of the work, the symbols a, e, γ, l, g, and h, denote quantities which have no solar perturbations; and that, consequently, the deviation of $\frac{2}{an}$ from a constant has the mass of the planet as a factor. Thus, as $\frac{dR}{dl}$ already has this factor, the additional terms, which would in this manner arise, would have the square of the mass of the planet as factor; these, as all other investigators, Delaunay expressly neglects.

With regard to the second assumption, in reference to which Mr. Neison makes what he thinks his chief point against Delaunay, let us consider what is the essential difference between Delaunay's method and that employed by the earlier investigators. Delaunay said to himself, Do not let us go back to the elements of the Keplerian ellipse every time we have to consider the action of a new force on the Moon, but let us determine our new wave of motion in such a way that it may be superposed on the curve which the Moon would describe under the action of all the forces previously considered, instead of on the Keplerian ellipse. At any stage of progress, in expressing the Moon's co-ordinates, there must, of necessity, appear in them six arbitrary constants which have been introduced by integration. Let us take these as variables, instead of the six elements of the Keplerian ellipse. This course demands that the differential equations employed by the earlier investigators should be somewhat modified. The modification appears as a change in the values of the quantities which Poisson denoted generally by the symbol $[a, b]$. Now, just as it would be absurd to maintain that the elements of the Keplerian ellipse suffer perturbations from the action of a centrobaric Earth, so it is absurd to maintain that the quantities a, e, γ, l, g and h, employed by Delaunay after he has got through with the solar perturbations and has arrived at the treatment of the planetary perturbations, and which are the elements of the curve which would be described by the Moon under the combined action of the Earth and Sun, suffer perturbations from the latter body. Yet Mr. Neison's argument, when divested of its obscurities, is seen to be nothing more or less than a plea that these quantities do suffer perturbations from the Sun.

To make the matter plainer, let us suppose that Delaunay, groping about in the dark, had fallen upon the Poissonian equations, and, thinking them to be his own, had used them as such; and, moreover, on making his substitutions, had made them only in the elliptic portion of the co-ordinates. Then he would have committed the very error Mr. Neison lays to his charge. But since he uses equations suitably modified to the new signification of the quantities a, e, &c., and, moreover, makes his substitutions in the complete expressions for the

Moon's co-ordinates, and not in the elliptic portion only, as the earlier investigators do, is it not plain that, by these two modifications, he obtains terms which he would not have obtained in the former supposed case? Now these terms, in sum, are precisely equivalent to those Mr. Neison accuses him of neglecting by omitting to include R''' in his disturbing function. Thus it is seen that Delaunay takes account of R''' in an indirect manner, the peculiar nature of his method absolving him from considering the terms arising from R''' as a separate class.

Perhaps the matter will be clearer still if we say that, just as in determining the solar perturbations we have no class of terms of the order of the product of the mass of the Earth by the mass of the Sun, simply because the Earth's action is considered as the principal force, so when we come to treat the planetary perturbations by Delaunay's method, there is no special class of terms of the order of the product of the Sun's mass by the planet's mass, for the reason that here the combined actions of the Earth and Sun are regarded as forming the principal force.

Next we must not pass over without notice the quite erroneous method Mr. Neison proposes (pp. 430, 431) for getting the proper expressions for the Poissonian quantities $[a, b]$; viz., by substituting for the elements in the expressions proper to the older form of the differential equations their complete values as functions of the time, and then neglecting all the periodic terms. It is very certain this procedure will not give the same values as Delaunay has, who obtains them by taking the partial derivatives of a, e, and γ with respect to the elements L, G, and H, which are the conjugates of l, g, and h.

Mr. Neison is not content with what he has already said to establish the serious imperfection of Delaunay's method, but fortifies himself in the belief of it by a new line of argument (pp. 432–437), where he gives his conception of the essential nature of Delaunay's transformations. But his argument is fatally vitiated because he will have it that the transformations in question are rigorously linear in their operation. Thus, to illustrate, suppose Delaunay has

Operation 1.

Replace a_0 by $a_1 + f_1(a_1, e, \&c.)$

Operation 2.

Replace a_1 by $a_2 + f_2(a_2, e_2, \&c.)$

(I use the subscripts, which Delaunay has not, that my meaning may be clear.) According to Mr. Neison's way of looking at things, these two operations are equivalent to

Replace a_0 by $a_2 + f_1(a_2, e_2, \&c.) + f_2(a_2, e_2, \&c.)$

Thus he fails to see that Delaunay intends the a_1, under the functional sign f_1, to be eliminated by the substitution of Operation 2, as well as the a_1 which is outside of it. In consequence he misses all the terms which are of the order of the product of f_1 by f_2.

Now, suppose that f_1 belongs to an operation which is concerned with solar perturbations, and f_2 to one concerned with planetary perturbations. Then Mr. Neison, by his erroneous interpretation of Delaunay's processes, fails to get some terms of the order of the product of the masses of the Sun and planet, which, nevertheless, Delaunay has. Now, these are the very terms Delaunay is accused of neglecting. And, what is sufficiently singular, Mr. Neison appears to regard the symbols a, e, &c., which are under the functional signs f_1, f_2, &c., as having everywhere throughout the whole series of operations the same signification, and as being absolute constants; so that, for him, all the f's are explicit functions of the time.

There is another way in which Mr. Neison's error may be illustrated. Suppose we write one of the differential equations of the Moon's motion in rectangular co-ordinates, thus

$$\frac{d^2x}{dt^2} - \frac{d\Omega_0}{dx} = \frac{dR^{(0)}}{dx} + e'\frac{dR^{(1)}}{dx} + e'^2\frac{dR^{(2)}}{dx} + \ldots + \beta\frac{dR_0}{dx} + m''\frac{dR_1}{dx} + \&c.,$$

where Ω_0 denotes the potential of the force exerted by a centrobaric Earth; and the portion of the disturbing function due to solar action has been broken into a number of parts $R^{(0)}$, $e'R^{(1)}$, $e'^2R^{(2)}$, &c., severally proportional to the various powers of the solar eccentricity e'; and βR_0 is the portion due to the figure of the Earth, β being a constant which measures the deviation of the Earth from a centrobaric body; in fine, $m''R_1$, is the portion due to the action of a planet whose mass is m''. Then Delaunay's way of proceeding is very similar to this: he first ascertains what would be the expressions for the Moon's co-ordinates were $R^{(0)}$ the complete disturbing function, by making variable the a, e, γ, l, g, and h which appear in the elliptic formulæ; he then transposes $R^{(0)}$ over to the left member of the equation, and the potential of the principal force is now no longer Ω_0 but $\Omega_0 + R^{(0)}$; he then proceeds to treat $e'R^{(1)}$ as if it alone constituted the whole of the disturbing function, using the elements a, e, γ, l, g, and h, which stand in his last expressions for the co-ordinates as variables, not those which belong to the elliptic expressions. When this is done, $e'R^{(1)}$ is transferred to the left member, and the potential of the principal force is now $\Omega_0 + R^{(0)} + e'R^{(1)}$, and the work is continued as before.

Now, Mr. Neison admits the legitimacy of all this as long as we are dealing with the portions of the disturbing function which arise from solar action; but says that, the moment we arrive at the term $m''R_1$, all changes. Then certain ghosts, as it were, of the portions $R^{(0)}$, $e'R^{(1)}$, &c., unbidden return to the

right member and trouble the portion $m''R_1$. Thus we have the strange spectacle of forces figuring at once as principal and as disturbing. Mr. Stockwell made a precisely similar objection to my elaboration of the inequalities due to the figure of the Earth, which was disposed of by Prof. Adams in a single sentence.

If all this be true, what becomes of the assertion, often reiterated, that, when the differential equations are written down, all the rest is a pure question of analysis? On Mr. Neison's and Mr. Stockwell's view, the analyst, who does the integrating, needs an astronomical or mechanical prompter at his elbow to inform him of the exact physical import of the constants β or m'', otherwise he will infallibly go wrong.

Washington,
1886, *Oct.* 14.

On Kepler's Problem. By Robert Bryant, B.A., B.Sc.

The solutions of this problem are usually given with a view of obtaining the eccentric anomaly directly from a series expanded in powers of the eccentricity, the application of which is in general very laborious.

The use of the differential formula

$$\frac{d\,\mathrm{E}}{d\,\mathrm{M}} = \frac{1}{1 - e\cos \mathrm{E}},$$

when an approximate value of E in a planetary orbit is known, involves less labour, while the results converge with great rapidity.

The two following series are given as readily offering the required approximate value of E in a planetary orbit, when one application of the differential formula usually gives the eccentric anomaly with sufficient accuracy. The series are so simple and so readily present themselves that they have probably been given before, but I have not met with them.

We have $\mathrm{M} = \mathrm{E} - e \sin \mathrm{E}$ with M and e, given to find E.

Lagrange's theorem may be concisely expressed thus:

If

$$y = z + x\phi(y), \text{ then } f(y) = \sum_{n=0}^{n=\infty} \frac{x^n}{\lfloor n} \frac{d^{n-1}}{d\,z^{n-1}} \left\{ \overline{\phi(z)}^n f'(z) \right\},$$

the interpretation of which when $n = 0$ is obvious.

If we expand sin E and cos E, we obtain

$$\sin \mathrm{E} = \sin \mathrm{M} + e \sin \mathrm{M} \cos \mathrm{M} + \frac{e^2}{2} \sin \mathrm{M}(2 - 3\sin^2 \mathrm{M}) + \frac{e^3}{3} \sin \mathrm{M} \cos \mathrm{M}(3 - 8\sin^2 \mathrm{M})$$
$$+ \frac{e^4}{24} \sin \mathrm{M}\,(24 - 136 \sin \mathrm{M} + 125 \sin^4 \mathrm{M}) + \ldots .$$

$$\cos \mathrm{E} = \cos \mathrm{M} - e \sin^2 \mathrm{M} - \frac{3}{2} e^2 \sin^2 \mathrm{M} \cos \mathrm{M} - \frac{2}{3} e^3 \sin^2 \mathrm{M}\,(3 - 4\sin^2 \mathrm{M})$$
$$+ \frac{5}{24} e^4 \sin^2 \mathrm{M} \cos \mathrm{M}(12 - 4\sin^2 \mathrm{M}) + \ldots .$$

These series are generally unsuited for the evaluation of E; but if we multiply them by sin M and cos M respectively, we get on addition

$$\cos(E-M) = 1 - \frac{e^2}{2}\sin^2 M - e^3 \sin^2 M \cos M - \frac{e^4}{24}\sin^2 M\,(36 - 49\sin^2 M) \quad \ldots .$$

or

$$\sin^2 \tfrac{1}{2}(E-M) = \frac{e^2 \sin^2 M}{4}(1 + 2e\cos M) + \frac{e^4}{24}\sin^2 M\,(36 - 49\sin^2 M) \qquad (A)$$

$$= \frac{e^2 \sin^2 M}{4}(1 + 2e\cos M) + \frac{e^4}{2}\sin M \sin 3M \text{ nearly} \qquad (B)$$

If, as Mr. Glaisher has suggested to me, we extract the square root of each side of (A), we get

$$\sin \tfrac{1}{2}(E-M) = \tfrac{1}{2} e \sin M \left\{ 1 + e\cos M + \frac{e^2}{12}(30 - 43\sin^2 M) \right\} \text{ nearly}$$

$$= \tfrac{1}{2} e \sin M \left\{ 1 + e\cos M + \frac{5e^2}{6}\frac{\sin 3M}{\sin M} \right\} \text{ nearly} \qquad (C)$$

In (B) and (C) the term involving sin 3 M may be neglected in obtaining an approximate value of E.

Again, in the above expression for Lagrange's theorem, if for a particular value of n we can make the quantity within the brackets constant, the corresponding term in $f(y)$ will vanish.

As the form of the function f is completely at our disposal, we may for a particular value of n put

$$\overline{\phi(z)}^n f'(z) = \text{const.}$$

or

$$f(z) = \alpha \int \frac{dz}{\phi(z)^n}$$

In the present case $\phi(M) = \sin M$.

If $n = 1$, we derive but little assistance.

If $n = 2$, we get $f(M) = \cot M$ (omitting a constant multiplier), and e^2 will not appear in our result.

If $n = 3$,

$$f(M) = -\frac{\cos M}{2\sin^2 M} + \tfrac{1}{2}\log\tan\frac{M}{2},$$

which is too complicated to assist us.

For values of n greater than 3 $f(M)$ is equally unsuitable.

Expanding, then, cot E, we get

$$\cot E = \cot M - \frac{e}{\sin^2 M} + \frac{e^3}{6}\sin M + \frac{e^4}{3}\sin^2 M$$

$$- \frac{e^5}{40}\sin M\,(27\sin^2 M - 20) \quad . \quad . \quad . \quad .$$

$$= \frac{\cos M - e}{\sin^2 M} + \frac{e^3}{6}\sin M \text{ nearly} \qquad (D)$$

The introduction of the term in e^3 is easily effected, and when M falls near $\pm 90°$, it is better to consider it, in which case it is evident that the terms involving e^4 and e^5 are very small.

In the first formula the sign of E−M is the same as that of sin M.

In the second formula, E > or < 180°, according as M > or < 180°. This fact and the sign of cot E are sufficient to determine the quadrant in which E is to be taken.

The following example will sufficiently illustrate the deduction of E by the methods above mentioned:

Suppose M = 250° for the planet *Eurynome* (79), for which $e = [9{\cdot}29078]$.

Formula C		Formula D	
$\frac{1}{2}$	9·6990	e	9·2908
sin M	−9·9730	Addition log	0·1962*
e	9·2908	cos M	−9·5341
cos M	−9·5341		0·2433
e cos M	−8·8249	cos M − e	−9·7303
	1·1751	sin M	−9·9730
$\frac{1}{1+e\cos M}$	0·0300*	cot E	9·7573
$\frac{1}{2}e$ sin M	−8·9628	E	240° 14′
sin ½(E−M)	−8·9328		
½(E−M)	−4° 55′		
E−M	−9 50		
E	240 10		

Having obtained an approximate value of E, we shall be greatly assisted in obtaining its true value by considerations such as the following.

In the first series the principal term neglected depends on $\sin M \frac{\sin 3M}{\sin M}$, or sin 3 M, which in this case is positive. Hence the deduced value of E is too small.

In the second series the principal term neglected depends on sin M, which in this case is negative. Hence the deduced value of cot E is too great, and since E lies in the third quadrant, it follows that E is too small.

If we then increase E by a few minutes of arc, we can work the results side by side with but little extra labour, the requisite logarithms being taken out at the same entry.

The correct value of E being unknown, the values adopted were 240° 14′ and 240° 20′. With these the calculation is as follows:—

* From Zech's *Tafeln der Additions- und Subtractionslogarithmen.*

e	9·29078	9·29078
sin E	−9·93855	−9·93898
Radius in minutes	3·53627	3·53627
e' sin E	−2·76560	−2·76603
Natural number	$-582'\cdot91 = -9^\circ\ 42'\cdot91$	$-583'\cdot49 = -9^\circ\ 43'\cdot49$
E	240° 14′	240° 20′
Deduced value of M	249 56·91	250 3·49
d M	+3·09	−3·49

We have thus, it will be seen, overstepped the true value of E in our estimate.

We have also

$1 - e \cos$ E	0·04430	0·04416
d M	+0·48996	−0·54283
d E	$+2'\cdot790$	$-3'\cdot153$
E	$240^\circ\ 16'\cdot790$	$240^\circ\ 16'\cdot847$

The mean of these differs from the true value of E by only $0''\cdot31$. Using seven figure logs we find $E = 240^\circ\ 16'\ 49''\cdot41$.

Note on the Star γ Equulei. By George Knott, B.A., LL.B.

In the spring of last year Mr. Hind pointed out to me that, in view of the Proper Motion of the star γ *Equulei*, there was ground for the inference that a small 11 mag. companion, detected by me in July 1867, was in physical connection with it. I have been hoping accordingly to obtain further measures of the pair, but have failed doing so until the present month.

I give below the results of the measures hitherto obtained by myself, together with a set by Mr. Burnham at an intermediate epoch:

1867·52	$P = 276^\circ\cdot83$	$D = 2''\cdot173$	Knott.
1867·57	276·85	2·089	——
1871·61	277·62	1·875	——
1877·72	274·5	2·1	Burnham.
1886·83	273·76	2·058	Knott.
1886·84	272·70		——

The measures of 1871·61 were taken under unfavourable circumstances, as appears from the note:—"B only to be seen on the most careful scrutiny; obs. most difficult." At my last epoch clouds came over before any measures of distance could be obtained. Mr. Burnham adds another small star, 12 mag., which I have not yet seen. His co-ordinates for it are: $P = 10^\circ\cdot0$, $D = 41''\cdot3$, Ep. 1877·72. It seems desirable that this star should be re-measured.

If now we take * the Proper Motion values assigned by Prof. Auwers, viz. :—in R.A. $+0^{s}\cdot0022$ and in Decl. $-0''\cdot167$, and starting from the epoch 1867·54 compute the present values of P. and D. on the assumption that the companion does not share in the motion of the principal star, we get $P = 321°\cdot72$, $D = 4''\cdot428$. A comparison of these numbers with my latest measures points distinctly to the conclusion that a physical connection subsists between the objects. The series of measures as a whole appears further to indicate a slight but decided decrease in the angle of position of the companion in nineteen years, while no change would seem to have taken place in the distance.

Knowles Lodge, Cuckfield: 1886, *November* 10.

On the Orbit of Σ 1757. By J. E. Gore.

I have computed the orbit of this binary star, by means of the graphical method, and find the following provisional elements :

Elements of Σ 1757.

P = 340·38 years.	$\Omega = 89°\ 45'$.
T = 1778·81.	$\lambda = 203°\ 14'$.
$e = 0\cdot2425$.	$a = 2''\cdot25$.
$\gamma = 45°\ 51'$.	$\mu = +1°\cdot057$.

The following is a comparison between the recorded observations, and the positions computed from the above elements :

Epoch.	Observer.	θ_o	θ_c	$\theta_o - \theta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$
		°	°	°	″	″	″
1825·37	Struve	10·0	10·75	−0·75	1·60	1·38	+0·2
1829·82	„	19·5	18·55	+0·95	1·44	1·45	−0·0
1832·39	Smyth	24·1	23·0	+1·10	1·5	1·49	+0·01
1833·38	Struve	23·9	24·6	−0·70	1 54	1·50	+0·04
1835·37	„	25·5	27 6	−2·10	1·66	1·53	+0·13
1836·42	„	29·4	29·1	+0·30	1·64	1·54	+0·10
1838·48	Smyth	31·0	32·1	−1·10	1·7	1·60	+0·10
1841·38	Mädler	36·0	36·1	−0·10	1·74	1 63	+0·11
1842·39	Dawes	37·4	37·4	0·00	1·67	1·66	+0·01
1842·52	Smyth	37·9	37·5	+0·40	1·7	1·66	+0·04
1843·45	Dawes	38·8	38·75	+0·05	—	1·69	—
1843·51	Kaiser	40·9	38·8	+2·10	—	1·69	—
1844·72	O. Struve	43·7	40·2	+3·50	1·89	1·71	+0·18
1845·88	Mädler	40·8	41·7	−0·90	2·02	1·74	+0·28

* I am indebted for these numbers to Mr. Hind.

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
1850·38	O. Struve	48°·8	46°·8	+2°·00	1″·85	1″·82	+0″·03
1852·38	Smyth	51·7	48·9	+2·80	2·0	1·88	+0·12
1853·09	Mädler	52·2	49·6	+2·60	2·05	1·89	+0·16
1853·73	Jacob	48·0	50·25	−2·25	2·14	1·89	+0·25
1854·37	Mädler	50·1	50·85	−0·75	2·16	1·90	+0·26
1855·31	„	51·3	51·8	−0·5	1·7	1·93	−0·23
1856·32	„	51·8	52·75	−0·95	1·5	1·95	−0·45
1856·42	Morton	51·9	52·85	−0·95	2·01	1·95	+0·06
1856·88	Secchi	52·9	53·35	−0·45	1·84	1·95	−0·11
1857·29	Morton	54·2	53·7	+0·5	2·00	1·97	+0·03
1858·08	Jacob	52·8	54·45	−1·65	1·76	1·98	−0·22
1858·37	Mädler	54·7	54·6	+0·1	1·91	1·98	−0·07
1859·36	„	53·7	55·5	−1·8	1·82	2·02	−0·20
1860·34	Dawes	54·3	56·4	−2·1	2·31	2·03	+0·28
1860·35	„	53·4	56·4	−3·00	2·08	2·03	+0·05
1863·32	Dembowski	59·0	58·96	+0·04	2·01	2·09	−0·08
1865·97	„	60·4	61·0	−0·6	2·09	2·13	−0·04
1866·01	O. Struve	60·8	61·03	−0·23	2·34	2·14	+0·20
1867·27	Talmage	63·7	62·1	+1·6	2·60	2·16	+0·44
1868·30	Dembowski	62·7	62·8	−0·1	2·04	2·18	−0·14
1869·22	Brünnow	63·4	63·53	−0·13	2·59	2·20	+0·39
1869·24	Talmage	64·3	63·53	+0·77		2·20	—
1870·15	Dembowski	63·5	64·2	−0·7	2·03	2·22	−0·19
1870·37	Talmage	64·1	64·3	−0·2	2·00	2·22	−0·22
1871·19	Dembowski	63·4	64·9	−1·5	2·13	2·24	−0·11
1872·33	Wilson & Seabroke	64·8	65·7	−0·9	2·30	2·25	+0·05
1872·37	Talmage	67·3	65·73	+1·57	-	2·25	—
1873·23	Wilson & Seabroke	64·0	66·45	−2·45	2·05	2·27	−0·22
1873·35	„ „	65·0	66·53	−1·53	2·00	2·27	−0·27
1874·32	„ „	65·5	67·25	−1·75	2·15	2·28	−0·13
1874·32	Talmage	69·8	67·25	+2·55	(1·08)?	2·28	(−1·20)?
1874·41	Wilson & Seabroke	64·2	67·31	−3·11	2·16	2·28	−0·12
1875·31	Schiaparelli	66·6	67·8	−1·2	2·00	2·29	−0·29
1876·36	Wilson & Seabroke	67·2	68·45	−1·25	2·15	2·30	−0·15
1876·41	„ „	66·5	68·48	−1·98	2·21	2·30	−0·09
1879·40	Hall	68·9	70·5	−1·60	2·33	2·35	−0·02
1879·470	Schiaparelli	67·98	70·5	−2·52	2·462	2·35	+0·112
1882·467	„	69·38	72·43	−3·05	2·314	2·42	−0·106
1883·21	Engelmann	70·44	72·8	−2·36	2·623	2·43	+0·193

The formulæ for calculation of an ephemeris are as follows:

$$(1)\quad u - 13{\cdot}89 \sin u = +1^{\circ}{\cdot}057\,(t - 1778{\cdot}81),$$

$$(2)\quad \tan \tfrac{1}{2}V = 1{\cdot}28 \tan \tfrac{1}{2}u,$$

$$(3)\quad \tan(\theta_c - 89^{\circ}\,45') = 0{\cdot}6965 \tan(V + 203^{\circ}\,14').$$

$$(4)\quad \rho = 2''{\cdot}25\,(1 - 0{\cdot}2425 \cos u)\frac{\cos(V + 203^{\circ}\,14')}{\cos(\theta_c - 89^{\circ}\,45')};$$

where u is the eccentric anomaly, and V the true anomaly for the epoch t, θ_c the required position angle, and ρ the distance.

The position of the star is for 1886·0

R.A. $13^{h}\ 28^{m}\ 29^{s}$

$+0^{\circ}\ 16'\ 6''$.

It is Lalande 25087, and lies closely *np ζ Virginis*. It was estimated 7^{m} by Lalande, and 7·0 at Cordoba. According to Struve the magnitudes of the components are 7·8 and 8·9.

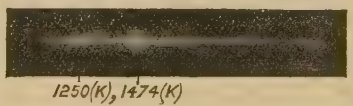
The orbit has been previously computed by Casey, who finds a period of 401·0 years, with T = 1797·42, and $e = 0{\cdot}5079$.

Ballysodare, Co. Sligo:
1886, *Oct.* 14.

Reply to certain Questions raised before the Royal Astronomical Society at the Meeting on 1886, *March* 12, *concerning the matter detailed in a Paper entitled "Bright Lines in Stellar Spectra."* By O. T. Sherman.

(*Communicated by the Secretaries.*)

The object of the method employed is to render the image of the bright line light as broad and intense as may be, and the intensity of the background light a minimum. A successful application is presented in the spectrum of *Nova Andromedæ*, which is shown in an adjoining cut.* Along a faint bluish line



Portion of the Spectrum of Nova Andromedæ.

there were seen bright stellar images surrounded by a haze. These were termed bright lines.

In practice the background light is often sufficiently intense

* The haze surrounding the stellar image is somewhat exaggerated in the drawing.

to cut down the haze surrounding the point, so that the image appears as a bright knot, fuzzy or sharply bounded, beading or embedded in the bright linear spectrum. Such is the case with *β Lyræ* or *γ Cassiopeiæ*, as seen with the means at command.

One has to distinguish between bright line, bright background space, and mere disturbance in the light of the spectrum. The principle upon which the discrimination is made is that the bright background space being the effect of contrast remains constant in both place and intensity. The disturbance in the light of the star is constant in neither intensity nor position. The bright line is constant in place but not in intensity. For each star, therefore, an extended series of observations is necessary.

The first remarks made concern (*a*) the adjustment of the instrument; (*b*) the action of the lines; (*c*) the position of the cylindrical lens.

(*a*) "First, 'previous to each night's work, the instrument was adjusted upon the Sun; a solar spot when possible being brought sharply in focus on the jaws of the slit.' This would seem a proper and necessary adjustment, and would suffice for the centre of the spectrum; but for the extreme rays, especially the blue and violet, the spectroscope would not be in the proper focus of the equatorial. There is a paragraph in Mr. Sherman's Paper which at least suggests that the extreme ends of the spectrum suffered in this way. . . ." The adjustments of the spectroscope were such as to give good definition for the solar spectrum. It was presumed they would also for the stellar. The adjustments have been regarded. Also two-thirds of the lines announced for *γ Cassiopeiæ* lie between D_3 and H $\gamma^{(1)}$,* a space not encroaching very far on the extreme ends of the spectrum. It is thought the remark will hold generally true.

(*b*) "There is a paragraph in Mr. Sherman's Paper which at least suggests that the extreme ends of the spectrum suffered in this way: 'At the red end, under a sharp focus, they' (the bright lines) 'stand out the full breadth of the spectrum, bearing somewhat the same relation to the background as the prominences to the solar spectrum. In the brighter portion of the spectrum they are cut down to bright star points. At the blue end they become more distinct, but not so sharp as at the red. At times they shine with almost a metallic brilliancy; at other times they are faint, faded, and easily passed over. Certain sets appear to be prominent at times; others at other times.' It seems very difficult to believe that this can be a description of true stellar bright lines, while it is quite conceivable that lines due to some instrumental effect might present just such an appearance in a spectroscope, adjusted as Mr. Sherman's seems to have been, only for the centre of the spectrum. . . ."

There are at least two other observers who agree as to the

* American Journal of Science, Dec. 1885.

action of the bright line. A note taken from the *Astronomische Nachrichten*, Nos. 2651–2652, is copied from the *Observatory* of April, 1885.

"*Variations in the Spectrum of β Lyræ.*—In the summer and autumn of 1883, Dr. N. de Konkoly and Herr E. von Gothard detected a certain amount of variability in the C, D_3 and F lines in the spectra of *γ Cassiopeiæ* and *β Lyræ*, in which they are frequently seen to shine as bright lines. During 1884, Herr von Gothard has followed up his investigations and observed the spectrum of *β Lyræ* on thirty nights. On nine of these occasions the D_3 line was seen to be more or less bright. On July 13 it was even described as 'almost dazzling'; on several other nights its presence was only suspected; on ten nights no trace of it was seen, so that it presented on different occasions every possible degree of change of brightness from great brilliancy down to total disappearance. The C line was also seen to be reversed on many occasions, and was frequently very brilliant, but on others it was only faint, was difficult to see, or was evidently a dark line. The F line was not so often noticed to appear bright; its reversal would naturally be less easily observed than that of C or D_3. Herr von Gothard was not able to satisfactorily determine the length of the period of variability; it was evidently very short, and a period of about seven days seemed to suit the observations fairly well. It should be added that the three lines appear to vary in perfect accord with each other . . . ."

Again, "both show bright lines of hydrogen and helium, so that the peculiarity of their condition probably consists in the unusual extent and intense ignition of their chromospheric surroundings. But this condition is subject to fluctuations. The brilliant rays indicative of it died out during nine years, 1874–1883. . . ." *

Again, the bright lines of the solar chromosphere show a similar variation in both visibility and frequency, as is shown in the frequency and maximum brilliancy numbers in Young's "Catalogue of Bright Lines in the Spectrum of the Solar Atmosphere." †

Again, one might appeal to our knowledge derived from "new" or "temporary" stars—for example, the changes in the spectrum of T *Coronæ*.‡

Again, a similar action is not entirely unknown even in laboratory work. For the sake of an example we quote,§ "When the carbonic acid is displaced by hydrogen, the hydrogen lines appear, the hydro-carbon flame and the triple sets remaining bright, but in this gas the flame group at 4310 is particularly well marked, and *the carbon line at 4266 keeps flashing in occa-*

* History of Astronomy during the Nineteenth Century, Clerke, p. 420.

† American Journal of Science, Nov. 1872.

‡ History of Astronomy during the Nineteenth Century, Clerke, p. 422.

§ On the Origin of the Hydro-Carbon Flame Spectrum, Profs. G. D. Liveing and J. Dewar, Proc. Roy. Soc. Vol. 34, 1882–1883, p. 429.

sionally." Or, in general, examples might be drawn from the whole range of phenomena showing change in spectra depending upon temperature or upon mechanical mixture with some other gas.*

(*c*) "Particularly as he placed his cylindrical lens not before the slit, nor even in the viewing telescope, but between the eye-piece and his eye."

The cylindrical lens need have and properly has no place in the arrangement. Used at the commencement of the work, it has long since been abandoned. As bearing on the point, however, the following quotation which has come to my knowledge within a day or two is not without interest. It comes from one who, having searched in the same field without being satisfied, makes suggestions for those that follow, "and to ask others with greater optical power to search for the lines, *taking the precaution to use the cylindrical lens close to the eye*, and not to apply it to the instrument until the rays to be examined are absolutely in focus on the slit, *if a slit is used*. It is possible scintillation may help matters." †

Under the second head is treated (*a*) the width of the slit; (*b*) the accuracy of the measures; (*c*) the generality of the appearances; (*d*) the fact that they have not been observed before.

Second (*a*). "Mr. Sherman used an unusually wide slit, '$5^{mm.}$ or more.' I think most stellar spectroscopists will pronounce this to have been fully 100 times too wide. $5^{mm.}$ in the focus of the 8-inch object-glass would correspond to 6′ of arc. It seems hard to see what purpose a slit of so great a width would serve, and in what essential feature it differed from no slit at all."

It practically is no slit at all. A glance at the quotation just above is not without interest. However wide the metallic jaws may be, the practical slit is the stellar diffraction shield for an eight-inch glass, about three seconds of arc in diameter. ‡

(*b*) "And it is also difficult to place much confidence in measures made with so wide a slit, especially as the collimator only measures 6 inches in focal length, so that no stress can be laid upon the correspondence between the bright lines observed and those seen in the solar chromosphere."

Since the practical slit is three seconds in place of six minutes, it is hoped that this objection falls. The light of the shield fades off rapidly towards the edge, leaving a sharp central point to be set upon, or a fuzzy disc to be bisected. The measures seem therefore, in point of accuracy, comparable with

* See the work of Profs. Liveing and Dewar. Proc. Roy. Soc. Vols. 27 and 36.

† Note on Bright Lines in the Spectra of Stars and Nebulæ. By J. Norman Lockyer. Proc. Roy. Soc. Vol. 27, p. 51.

‡ Hermann Struve, Mém. de l'Acad. Impériale des Sciences de St. Pétersbourg, VII^e^ Série, Tome XXX. No. 8. Airy, Transactions of the Cambridge Philosophical Society, Vol. V. part iii.

those obtainable with a slit somewhat less in width than the stellar diffraction image, and some stress seems due to their approximate agreement with the solar atmospheric lines. A greater conditioning circumstance seems to be the use of a thick wire.

(*c*) "The most suspicious circumstance of all, however, is, I think, that so far Mr. Sherman has never failed to see bright lines in any star which he has examined. . . . . I have had occasion to notice on more than one occasion that a stellar spectrum which is full of dark lines or bands may, when badly seen, give a very perfect illusion of bright lines; the dark lines escaping recognition as such, but producing their effect by making the parts of the spectrum most free from them shine out by contrast like a veritable chromospheric spectrum."

The method by which it was hoped to distinguish between bright background space is already explained. It was hasty to claim bright lines for numerous stars. The announcement should have awaited the completion of the series of observations. Credence for the statement without such a series cannot be asked, but it is asked that the result of the series be awaited.

(*d*) "And that though 'sometimes they shine with almost metallic brilliancy,' yet no previous observer has detected them."

The spectroscopic arrangement is considerably different from that usually employed. Although no assertion of the existence of the lines has reached me, there is at least one who has suspected them, as the following quotation shows:* "Two years ago (1876) I searched for indications of a large chromosphere in the case of *α Lyræ* and some other stars. I believe I had glimpses of bright lines at F and *b*, but if this discussion [between Huggins and Stone] had not arisen I should have still hesitated to mention this, as I had been hoping for an increase of optical power."

In closing one may perhaps draw attention to this fact, that the result is not at variance with our best knowledge of stellar constitution. Speaking of the lesson to be learned from T *Coronæ*, a recent writer says: "No clear dividing line can be drawn between stars and nebulæ, but that in what are called planetary nebulæ on the one side and in 'gaseous stars' (those giving a spectrum of bright lines) on the other, we meet with transitional forms serving to bridge the gap"† between the faintly lucent nebula and the highly-finished star, and among the stars themselves one may readily pursue every value of the ratio expressing the relation between the light from the stellar nucleus and from the stellar atmosphere. While the arrangement which will bring out the absorption lines will hide all but the brightest of the gaseous lines, the method just described is, I think, bringing out those lines which belong to the gaseous envelope.

* Note on Bright Lines in the Spectra of Stars and Nebulæ. By J. Norman Lockyer. Proc. Roy. Soc. Vol. 27, p. 50.

† History of Astronomy during the Nineteenth Century, Clerke, pp. 422–423.

Bands observed in the Spectra of Sun-spots at Stonyhurst Observatory. By the Rev. A. Cortie, S.J.

(*Communicated by the Rev. S. J. Perry.*)

There are three kinds of bands which have been observed in the spectra of Sun-spots. The first, which is a certain fuzzy appearance surrounding the widened portions of the dark lines, has been very frequently seen, and is only a particular phase of the widening of the line. The second is an intensifying of the general absorption due to a Sun-spot in particular parts of the spectrum. The third is the appearance of real bands in the selective absorption due to a spot. The present paper contains some observations of each of these kinds of bands.

With regard to the hazy appearance or fuzziness surrounding a widened line, it is usually and most easily observed on the D lines, although not peculiar to them. In a spot in the S. F. quadrant of the Sun observed on November 15, 1883, the widening of all the lines, instead of a dark and distinct thickening of the same, presented the appearance of a penumbral shade at either side of the dark central line. But this haziness has been most markedly attached to the D lines on several occasions. Thus on September 29, 1884, and on January 14, 1886, these two lines were not only widened and fuzzy, but were also reversed in one portion of their length. Sometimes the haze exists surrounding the lines, while the lines themselves are not widened, as on October 2 and 3 of the present year in a small spot. In the part of the spectrum between D and C, Ångström gives a line as due to *Na* at 6160·23 a little more refrangible than a strong *Ca* line at 6160·40. This *Na* line is drawn as double in the maps of Fievez and Piazzi Smyth, and with good definition, and using a dispersion of twelve prisms, it has been usually so seen. This double is always remarkably widened in the spectra of spots, and, moreover, the widening is of the nature of the fuzzy band seen at times in connection with the D lines. If a moderate dispersion of six prisms be used, it appears as if the *Ca* line adjoining this faint double was considerably widened and displaced towards the violet. But on using a great dispersion the widening is seen to be principally due to these faint *Na* lines, although the thick *Ca* line is usually also affected. On June 25, 1885, and on January 14, 1886, the widened *Ca* line was seen running through the haze due to these *Na* lines. In the small spot of October 2 of the present year, the band due to these lines was at least one-tenth mètre in breadth. Finally it may be mentioned in connection with the D lines, that when the widening on the two sides is unequal, the balance is almost invariably in favour of the violet or more refrangible side of the lines.

The second kind of band is due to the intensifying of the general absorption in particular parts of the spectrum of Sun-spots. This phenomenon has only been observed on four occasions during the course of as many years of observation. On May 11, 1884, the general absorption of a large spot N F had a blurred appearance in the red end, and besides was so dark that it almost masked the selective absorption, rendering it very difficult of observation. The same appearance was seen on May 18 of the same year in a black spot S P. Again, on June 25, 1885, the lines about 6172·5 were masked by this blurring effect; and, finally, on February 6, 1886, the relative darkness of the general absorption in the red end was much more intense than in the rest of the spectrum. This last observation was made between 2 and 3 P.M. in a hazy sky. In the Greenwich observations of the great Sun-spot of November 19, 1882, it is noted that "the general absorption was not uniform; here and there there were ill-defined patches, noticeably darker than the rest of the spectrum." Again, although Prof. Young, using a Rowland grating attached to a 23-inch equatorial, has succeeded in resolving even the band of continuous shade, due to a Sun-spot, into a series of fine dark lines with bright spaces (*Amer. Jour. Science*, vol. xxvi. November 1883), yet he remarks that "in the red, even with the highest dispersion, and under the most favourable circumstances of vision, the spot-spectrum appears simply as a continuous shade, crossed here and there by widened and darkened lines."

The last of the three kinds, into which we have divided this phenomenon of spot-bands, is perhaps the most important of all, because of its connection with the selective absorption of Sun-spots. The first recorded observations of these bands are those of Professor Young (*Nature*, December 12, 1872). With regard to their interpretation he states that "they would seem to point to such a reduction of temperature over the spot-nucleus as permits the formation of gaseous compounds by elements elsewhere dissociated." In the Greenwich Spectroscopic and Photographic Results for the years 1880–83 many observations of similar bands are recorded in the portion of the spectrum from D to F. At Stonyhurst the spot-spectrum is observed from D to B. The spectroscope employed is an automatic instrument by Browning, and the dispersion generally used is one of twelve prisms of 60°. Perhaps the region richest in the various phenomena of the spectra of Sun-spots in this part of the spectrum is that included between λ 6370·0 and C. Nine of the lines have coincident bright lines in the chromospheric spectrum as mapped by Young, and there are four dark basic lines. It is in this portion that the spot-bands have been most frequently seen, and two of them have been selected for particular attention and study. The bands were first noticed on February 28, 1885, especially a broad one lying between the lines λ 6438·35 and 6449·29, and they have been seen on eight

subsequent occasions. The number of bands so far reckoned is nine. Of these the two more particularly studied are situated the one near λ 6380·0 and the other at λ 6383, the positions being fixed by accompanying lines, and being most probably correct to within one-tenth mètre. On May 26 of the present year these two bands were most distinct in a spot of regular outline. The first adjoined the line λ 6379·99 on its less refrangible side. The second had no line at its edges but was diffused in appearance, although its tint was somewhat intensified towards the red end. The general appearance of these bands resembled a fluted spectrum, and some very faint lines could be traced from them into the ordinary spectrum. These two bands were again examined most carefully on July 2nd and 4th of the present year in magnificent definition. The general absorption given by the spot was one with well-defined edges. On the former of these dates the spot-band at λ 6379·99 was joined on to the line as observed on May 26. But on the 4th, when the general absorption was less intense, it no longer adjoined the line, but was clearly separated from it. Moreover, its appearance had altered, for it seemed to be formed by two or three lines very greatly widened. The companion band also seemed to be composed of three lines similarly affected. But these bands or groups of lines were due to the spot alone, for no trace of them could be detected when the spot was removed from the slit, and they stood out most clearly and distinctly in the darkest part of the umbra. On the 7th, when the spot had approached the limb, none of the bands were so distinct as formerly, although the definition was equally good. Yet they were visible in the spot, and nowhere else. In the small spot of October 2nd and 3rd no bands at all could be detected in the region between λ 6379·99 and C. On the 3rd, however, the lines at 6242·6 (A°) and 6305·0 (Fievez) had a banded appearance on their more refrangible side, possibly due to a displacement in that direction. It may be noted, however, that this line 6305·0 corresponds to a line in Young's diagram (*loc. cit.*) marked at K 796·2, which is depicted as enormously widened.

Finally, with regard to the two bands selected as typical of this third class, this must be remarked, that they occur in a portion of the spectrum in which Ångström marks no line, and in which the very great dispersion employed by Fievez and Piazzi Smyth gave in the first case two, and in the second three faint lines, about the position of the second band. Coincident with the first band there is absolutely no dark line mapped, which is true also for the bands between λ 6438·35 and λ 6449·29. This, coupled with the fact that they appear only in Sun-spots, and there are most intense in the umbra, shows them to belong exclusively to Sun-spot spectra. They are a phenomenon altogether distinct from the ordinary widened, or darkened, or obliterated line of such spectra. From fifteen to twenty such bands are recorded in the Greenwich observations,

nine have been seen at Stonyhurst, and always in the same positions. Even should higher dispersion resolve them into lines, such clusters of greatly widened lines occurring at certain definite positions in the spectra of some Sun-spots is a remarkable phenomenon well deserving the closest attention.

Note on Photographs of Stars in Cygnus taken in August 1886.
By Isaac Roberts.

The negatives which I now exhibit were taken with my 20-inch Reflector on the nights of August 17, 23, 24, and 25 this year, and they represent parts of the constellation *Cygnus*, corresponding with those photographed by MM. Henry with their 13-inch refractor in June and August 1885, copies of which have been presented to the Society as well as to some of the Fellows.

The celestial position of the centre of each plate is as follows:

		h m		° ′
No. 1	R.A.	21 2	Decl.	38 12
3	„	19 45	„	35 30
4	„	19 55	„	37 45
5	„	20 4	„	35 30

The enlargements have been made to the scale corresponding with that adopted by MM. Henry so as to facilitate comparisons between them. The time of exposure, namely, 60 minutes, is common to all the photographs.

If we compare these plates with those by MM. Henry there are striking differences observable in the sharpness of the margins of the star discs, in the density of the images, and in the number of stars photographed in 60 minutes by the two instruments respectively.

In the Henry plates the margins of the stars are remarkably sharp and clearly defined. The brightness or density of the images also, whether the stars are of the second or of the fifteenth magnitude, is equal in all without perceptible gradation. The reflector, on the contrary, shows the margins somewhat undefined, and the stars of the first to the third magnitude show prominently diffraction effects around them. Not less noticeable is the gradation of the light of the stars between the brightest and the faintest shown on the plates; the gradations are such that the stars are ultimately lost in the colour of the background or film, and to define their magnitudes will severely tax the powers of classification.

In drawing inferences from the relative numbers of the stars

photographed by the two instruments in sixty minutes, it must be remembered that besides the difference between them in principle and aperture, there may be difference in the sensitiveness of the plates used, also difference in the atmospheric conditions when the photographs were taken as well as difference in the method of developing the images; but, subject to these reservations, we may, in the absence of more exact methods, make approximate comparisons by counting the number of stars on a given area, such as a square inch, on the enlarged photographs respectively. In this manner I counted on one of the reflector photographs 109, 93, and 70, or an average of 91 stars on one square inch. The numbers on the corresponding areas on the refractor photograph were 59, 64, and 41, or an average of 55 stars on one square inch. It therefore appears that the reflector has over the refractor the advantage of number in the average ratio of nearly two stars to one.

In view of others entering upon the work of photographing the stars, and to save them much waste of time and resources, it would be desirable to make comparisons between the relative efficiency of existing refractors and reflectors as instruments for photographing.

The comparisons might be made in some such manner as the following:

1stly. A sufficient number of photographic dry plates should be obtained from some reliable maker. They should be made from one uniform admixture of emulsion, and the plates distributed among those who would engage in the enquiry.

2ndly. A given number, such as ten, of the plates should be exposed for thirty minutes each on ten different clear nights (one plate each night) upon such sky spaces as may be determined.

3rdly. The plates should be developed by the same chemical formulæ with an immersion in the developer, say of five minutes.

4thly. The number of stars upon each plate should be counted and the density of the images noted.

The result would at least be some guide to those who intend to engage in photographing the stars, to enable them to choose their instruments and to compare their work afterwards. In addition to the information thus to be obtained, a report upon the driving-clock used in the experiments should be prepared, and its errors given during each exposure of the plates. An accurate and reliable driving-clock and gearing are absolutely essential in star photography, for any appreciable error would distort the star discs, and so prevent accurate micrometrical measurements of their relative positions being made.

Note on two Photographs of the Nebulæ in the Pleiades taken in October 1886. By Isaac Roberts.

On the night of October 23 (last month), I had an opportunity of taking a photograph of the *Pleiades*, and intended to expose the plate for three hours so as to be able to compare the result with that obtained by MM. Henry, but clouds caused me to stop the exposure after eighty-nine minutes. The plate when developed showed clearly that the stars *Alcyone*, *Maja*, *Electra*, and *Merope* are surrounded by nebulæ, indications of which about three of the stars are shown on MM. Henry's chart, which is published in the *Annales de l'Observatoire de Paris*.

On the following night (the 24th) I exposed another plate for three hours, which, after development, showed that not only are the stars which I have just named surrounded by nebulæ, but that the nebulosity extends in streamers and fleecy masses, till it seems almost to fill the spaces between the stars, and to extend far beyond them. It suggests the probability that these principal stars in the *Pleiades*, together with many of the stars around them, are involved either directly or else in sight alignment with one vast nebula. The negatives and the enlargements to six diameters, which I now exhibit, will enable you to appreciate and to form your own judgment as to the credibility of the evidence upon which these inferences rest, and I await with watchfulness for a clear interval which will enable me to try an exposure of *five hours* in order to obtain more light upon the subject.

The star discs upon the photographs are somewhat deformed by refraction and uncorrected instrumental movements, but I think you will not have much difficulty in mentally making the corrections necessary to form accurate judgment; and I anticipate being able to obviate this slight distortion in future exposures.

The Orbit of Comet II., 1883, *discovered by Mr. Ross.* By Lieut.-General J. F. Tennant, R.E., F.R.S.

Some considerable time ago I made some efforts to get a satisfactory orbit for this comet, but circumstances were unfavourable and I had to give it up. More recently I was induced to take it up to see if there were any real departure from a Parabolic Orbit such as Mr. Bryant found, or whether his result was only due to the selection he had made of observations. My conclusion was that there was no real justification for departing from the parabola. Then I found that the compilers of the *Annuaire du Bureau des Longitudes* had adopted Mr. Bryant's

results, and I made some further calculations. I now offer my results for publication lest what I think a mistake should pass unnoticed.

Starting with Mr. Tebbutt's orbit as an approximation, I computed an ephemeris from January 10 to February 6, 1884, for each Greenwich noon, and with this compared the whole of the observations at Melbourne,* Windsor, and Madras. The Melbourne observation of January 17 is affected with considerable error, and I was obliged to reject it. The mean of the observations at Madras on January 26, and the observations at Madras on January 30, at Melbourne on February 1, and Windsor on February 2, are somewhat discordant, but I have not excluded them, as I did not think they would materially affect my result. I then proceeded to obtain normal places, and found the error of my ephemeris to be

On Jan. 17·0 in R.A.	$+51''.4$	in Decl. $-34''.3$
26·5	$+39''.8$	$-26''.0$
30·0	$+29''.8$	$-24''.0$

From the places found by applying these corrections to the ephemeris I computed a parabolic orbit with the following result:

T = Perihelion Passage 1883, Dec. 25·31928

log q = 9·4938146

$\pi = 43^\circ\ 30'\ 48''.5$

$\Omega = 264\ 33\ 13.5$ } Mean Equinox, Jan. 0, 1884

$L = 114\ 59\ 03.1$

which give at the middle date

$$\lambda_c - \lambda_o = +11''.2$$
$$\beta_c - \beta_o = -\ 9''.6$$

a result larger than I had anticipated from the errors of the ephemeris at the selected times.

By forming equations of condition for the effects of small changes in the elements, I obtained the following elliptic orbit:

T = 1883, Dec. 25·320145

log q = 9·4899874

e = 0·9980441

$\pi = 43^\circ\ 33'\ 16''.8$

$\Omega = 264\ 51\ 04.0$ } Mean Equinox, Jan. 0, 1884.

$L = 115\ 03\ 44.3$

* I have used the corrected observations in the "Astronomische Nachrichten." Those published in the *Monthly Notices* have great error.

The period would be 1,986 years, but, of course, the deduction of so long a period from such data is not to be considered as giving it any certainty.

Having the equations of condition I proceeded to see what would be the most probable parabola from the normal places, and found

$$T = 1883, \text{ Dec. } 25{\cdot}319222$$
$$\log q = 9{\cdot}4938953$$
$$\left.\begin{aligned} \pi &= 43^\circ\ 30'\ 40''{\cdot}4 \\ \Omega &= 264\ 32\ 54{\cdot}4 \\ L &= 114\ 39\ 01{\cdot}9 \end{aligned}\right\} \text{Equinox as before.}$$

The errors at the times of the normal places, as obtained from the equations of condition.

C−O at 1st date in R.A.	$+4''{\cdot}43$	in Decl. $+1''{\cdot}74$
2nd	$-7{\cdot}98$	$+7{\cdot}42$
3rd	$+2{\cdot}49$	$-1{\cdot}76$

leading to a probable error of $\pm 4''{\cdot}8$ in the determination of one element, which seems possible enough when one looks at the individual observations. But it would have been preferable to give more weight to the middle place, as the observations about the middle of the apparition are the best.

On the whole I think that we have no sufficient data for assigning elliptic elements, and that the parabola last given is about as good as any which can be deduced from the observations, though the real orbit may be an ellipse of long period.

Observations of Comet f 1886 (*Barnard*), *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations were made with the East or Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of Declination.

Comet f 1886.

1886.	Greenwich Mean Solar Time. h m s	Observer.	☄−★ R.A. m s	Corr. for Par. and Refract. in R.A. s	☄−★ N.P.D. ′ ″	Corr. for Par. and Refract. in N.P.D. ″	No. of Comp.	Apparent R.A. h m s	Apparent N.P.D. ° ′ ″	Comp. Star.
Nov. 2	16 8 24	A.D.	−1 18·89	−0·14	+14 15·0	−2·1	6	11 53 44·02	82 59 24·6	*a*
4	17 0 9	H.	+0 5·40	−0·22	− 6 32·5	−4·9	1			*b*
4	17 37 4		+0 37·63	−0·18	+ 1 59·6	−4·4	3			*c*
5	16 47 10	T.	+1 47·77	−0·23	− 6 34·9	−4·9	3			*d*
5	16 48 23		+1 21·90	−0·21	− 44·6	−4·5	4	12 7 4·67	81 59 5·3	*e*
7	18 0 0	L.	+2 31·00	−0·17	− 3 8·5	−4·8	10	12 15 11·02	81 15 2·0	*f*

Mean Places of Comparison Stars.

Star's Name.	R.A. 1886·0. h m s	N.P.D. 1886·0. ° ′ ″	Authority.
(*a*) π Virginis	11 57 1·87	82 45 0·5	Nautical Almanac
(*b*) Arg. Z. +7°−2515	12 1 41·9	82 27·0	Bonn Obs. vol. iii.
(*c*) Arg. Z. +7°−2514	12 1 20·6	82 16·3	Bonn Obs. vol. iii.
(*d*) Arg. Z. +8°−2575	12 5 14·6	82 6·4	Bonn Obs. vol. iii.
(*e*) W.B. XII. 49	12 5 41·95	81 59 45·0	Schjellerup
(*f*) W.B. XII. 164	12 12 39·16	81 18 5·8	Schjellerup

Notes.

November 2.—Comet bright, with nucleus and faint tail. November 5.—Sky hazy. Comet bright, with nucleus.
November 7.—Comet very bright, stellar nucleus.

The observations are corrected for Parallax and Refraction. The initials A.D., T., L., and H. are those of Mr. Downing, Mr. Thackeray, Mr. Lewis, and Mr. Hollis respectively.

Royal Observatory, Greenwich:
1886, *November* 11.

Observations of Comets made at Mr. Wigglesworth's Observatory with the 15·5-inch Cooke Refractor. By J. G. Lohse.

Comet 1885 *a, Barnard.*

Date	Scarborough Mean Time	$\Delta\alpha \cos\delta$	$\Delta\delta$	α	δ	Num. of Comp.
1885	h m s	s		h m s		
July 17	11 51 42	+ 25 27	—	17 3 54·79	—	7

Comet 1885 *d, Fabry.*

1885	h m s	s	′ ″	h m s	° ′ ″	
Dec. 7	8 37 23	— 19·03	+ 2 4·8	0 25 9·54	+ 20 52 43·8	5
„ 24	8 41 2	+ 23·38	+ 1 23·6	23 54 16·75	+ 20 40 52·1	6,6
„ „	9 12 40	+ 21·54	+ 1 22·5	23 54 14·91	+ 20 40 51·0	3
„ 28	7 35 15	— 5·26	+ 2 13·6	23 48 58·95	+ 20 44 20·4	7

Comet 1885 *e, Barnard.*

1885	h m s	m	s	′ ″	h m s	° ′ ″	
Dec. 6	11 53 53	—	43·48	— 1 13·9	4 14 57·79	+ 4 55 56·4	8,8
„ 7	12 24 15	—	20·87	— 6 21·3	4 12 29·90	+ 5 3 53·2	4
„ 10	11 11 12	—	3·56	+ 7 38·2	4 5 13·27	+ 5 21 1·5	9
„ 13	12 27 7	+	26·98	+ 19·6	3 57 33·46	+ 5 40 31·6	8
„ 28	11 45 0	— 1	32·55	+ 48·5	3 19 54·70	+ 7 41 53·1	5,5
1886							
Jan. 2	10 26 45	—	22·95	— 3 59·7	3 8 13·97	+ 8 29 59·7	5

Adopted Mean Places of Comparison Stars for 1885·0 *and* 1886·0.

	α	Redn.	δ	Redn.	Authority.
1885	h m s	s	° ′ ″	″	
July 17	17 3 26·57	+ 2·95	— 10 22 15·8	+ 7·9	B.-W., 17^h 3.
Dec. 7	0 25 25·13	+ 3·44	+ 20 50 14·0	+ 25·0	8·5 mag. * connected with B.-W.$_2$ 0^h 838 + 840 / 2
	0 33 52·56		+ 20 48 27·1		
24	23 53 50·41	+ 2·96	+ 20 39 2·9	+ 25·6	B.-W.$_2$ 23^h 1096.
28	23 49 1·35	+ 2·86	+ 20 41 41·4	+ 25·4	9 mag. * connected with B.B. VI. + 20″ 5397.
	23 50 12·68		+ 20 42 30·3		
Dec. 6	4 15 37·16	+ 4·11	+ 4 57 8·9	+ 1·4	11 mag. * connected with Glasg. Cat. 1067.
	4 19 50·69		+ 4 53 10·1		
7	4 12 46·65	+ 4·12	+ 5 10 12·9	+ 1·6	10 mag. * connected with Glasg. Cat. 992.
	4 5 12·71		+ 5 13 21·2		
10	4 5 12·71	+ 4·12	+ 5 13 21·2	+ 2·1	Do.
13	3 57 2·35	+ 4·13	+ 5 40 9·3	+ 2·7	ν Tauri, Berliner Jahrb.
28	3 21 23·23	+ 4·02	+ 7 40 59·1	+ 5·5	B.B. VI + 7° 510.
1886					
Jan. 2	3 8 36·20	+ 0·72	+ 8 34 6·4	— 7·0	Ast. Nach. 2709 [$\frac{1}{3}$ (Sant, + 8° 40 + Schj. 927–28 + Glasg. 748)].

Mr. Wigglesworth's Observatory,
Scarborough : 10 *Nov.*, 1886.

Notes.

July 17.—The comet is faint and round; it becomes gradually brighter towards the middle, but has no real nucleus. It is much fainter than on July 14; it was well seen on that day, but clouds came on before an observation could be obtained.

December 24.—Comet Fabry is round and has a stellar nucleus; it is about 2′ in diameter, but still faint. Clouds lit up by the Moon were troublesome.

December 6.—Comet Barnard is faint and small. The coma extends farther on the following side than in other directions. The central bright part appears granulated, and equals in brightness about an 11th mag. star. The diameter of the comet is 4 to 5 seconds in time.

December 10.—The comet is decidedly more extended on the following side, and about of the same brightness as on December 6 and 7. The diameter is about 7 seconds.

December 28.—The comet was often barely visible through the faint clouds passing. At intervals it was snowing and very stormy. The comet is elongated on the following side, and the nucleus is brighter than that of comet *d*, but the latter seems to be the larger one, though the difference is very small.

January 2.—The sky being hazy the comet appeared very faint.

The observations were made with a wire micrometer by Merz, kindly lent by Lord Crawford. Only for the first observation a transit micrometer, with a set of fixed wires, was used.

Refraction has always been taken into account.

For the catalogue places of most of the comparison stars I am indebted to Dr. Copeland.

The co-ordinates of the Observatory have been taken from the 6-inch Survey Map, and are:

Longitude of Observatory $= 1^{m}38^{s}.9$ west of Greenwich.
Latitude „ $= +54^{\circ}\ 16'\ 30''$.

Observations of Phenomena of Jupiter's Satellites, made at Windsor, New South Wales, in the year 1886.
By John Tebbutt.

I send herewith my observations of phenomena of *Jupiter's* satellites during the current year. The Fellows will, doubtless, be glad to learn that I have added to my Observatory appliances a fine Equatorial Refractor of 8 inches aperture, with which I propose to continue not only the observations of the eclipses but also those of the transits and occultations. My telescope of $4\frac{1}{2}$ inches aperture was hardly equal to the work of observing the two last-mentioned phenomena. I also intend to follow more extensively the work of double star observation. The large Equatorial, which is driven by clockwork, was constructed by Grubb, of Dublin, for the late Dr. Bone, of Castlemaine, Victoria, and its object-glass, both from Mr. Ellery's and my own short experience with it, appears to be one of great excellence. In the accompanying table the telescope with which each observation was made is distinguished by the initial letter of the maker's name. C. and G. denote the Cooke and Grubb Equatorials of $4\frac{1}{2}$ and 8 inches aperture respectively.

Phenomena of Jupiter's Satellites.

Day of Obs.	Sat.	Phenomena.	Phase.	Telescope.	Power.	Windsor Mean Time. h m s	Correction to N. Ahnanac. m s
March 28	I.	Ecl. R.	First seen	C.	180	13 30 15·8	+ 1 26·0
28	I.	„ „	Full brightness	„	„	13 31 37·1	
28	IV.	„ D.	Last seen	„	130	14 38 32·9	−15 34·9
28	IV.	Ecl. R.	First seen	„	„	16 28 4·7	+ 8 53·9
April 1	III.	„ „	First seen	„	180	6 55 19·2	+ 1 13·4
1	III.	„ „	Full brightness	„	„	7 0 43·4	
4	I.	„ „	First seen	„	„	15 22 48·2	+ 0 8·4
4	I.	„ „	Full brightness	„	„	15 25 49·2	
22	I.	„ „	First seen	„	„	8 7 55·1	+ 0 7·3
22	I.	„ „	Full brightness	„	„	8 10 6·2	
24	II.	„ „	First seen	„	„	6 36 12·2	− 0 13·6

Day of Obs.	Sat.	Phenomena.	Phase.	Telescope.	Power.	Windsor Mean Time. h m s	Correction to N. Almanac. m s
April 24	II.	Ecl. R.	Full brightness	C.	180	6 38 7·9	
May 1	II.	,, ,,	First seen	,,	,,	9 13 13·4	− 0 2·4
1	II.	,, ,,	Full brightness	,,	,,	9 15 22·1	
8	I.	,, ,,	First seen	,,	40	6 25 0·8	− 0 2·0
8	II.	,, ,,	First seen	,,	,,	11 49 49·6	− 0 15·2
8	II.	,, ,,	Full brightness	,,	,,	11 52 37·1	
14	III.	,, ,,	First seen	,,	,,	6 40 45·5	− 0 14·3
14	III.	,, ,,	Full brightness	,,	,,	6 46 55·9	
15	I.	,, ,,	First seen	,,	,,	8 19 42·2	+ 0 9·4
21	III.	,, D.	Fading	,,	,,	7 59 12·0	
21	III.	,, ,,	Last seen	,,	,,	8 4 1·7	+ 3 48·9
21	III.	,, R.	First seen	,,	,,	10 39 18·3	+ 0 5·5
21	III.	,, ,,	Full brightness	,,	,,	10 44 18·5	
22	I.	Occ. D.	Ext. contact	G.	350	6 51 41·7	
22	I.	,, ,,	Total disapp.	,,	,,	6 55 7·2	
22	I.	Ecl. R.	First seen	,,	225	10 13 51·1	− 0 16·7
22	I.	,, ,,	Full brightness	,,	,,	10 15 38·8	
31	I.	,, ,,	First seen	C.	40	6 37 17·7	− 0 8·1
June 25	II.	Tr. Ingr.	Ext. contact	G.	170	5 40 14·3	
25	II.	,, ,,	Int. contact	,,	,,	5 44 48·5	
25	II.	,, Egr.	Int. contact	,,	,,	8 24 50·9	

Day of Obs.		Sat.	Phenomena.	Phase.	Telescope.	Power.	Windsor Mean Time. h m s	Correction to N. Almanac. m s
June	25	II.	Tr. Egr.	Ext. contact	G.	170	8 29 31·2	
	26	III.	Ecl. R.	First seen	,,	,,	6 29 16·7	− 0 48·1
	26	III.	,, ,,	Full brightness	,,	,,	6 34 21·9	
	27	II.	,, ,,	First seen	,,	,,	6 4 50·6	− 0 44·2
	29	I.	Tr. Ingr.	Ext. contact	,,	,,	8 8 41·8	
	29	I.	,, ,,	Int. contact	,,	,,	8 11 26·4	
July	3	III.	Ecl. D.	Fading	,,	,,	7 56 12·9	
	3	III.	,, ,,	Last seen	,,	,,	8 2 4·9	+ 5 25·1
	4	II.	,, R.	First seen	,,	,,	8 41 11·1	− 0 19·7
	4	II.	,, ,,	Full brightness	,,	,,	8 43 14·2	
	10	III.	Occ. D.	Ext. contact	,,	225	6 46 2·4	
	10	III.	,, ,,	Total disapp.	,,	,,	6 55 55·7	
	11	II.	,, ,,	Ext. contact	,,	,,	6 7 5·0	
	11	II.	,, ,,	Total disapp.	,,	,,	6 11 39·2	
	28	III.	Tr. Ingr.	Ext. contact	,,	175	5 15 22·2	
	28	III.	,, ,,	Int. contact	,,	,,	5 21 41·2	
Aug.	8	III.	Ecl. R.	First seen	,,	170	6 19 53·9	− 0 4·9
	8	III.	,, ,,	Full brightness	,,	,,	6 23 14·8	
	8	I.	,, ,,	First seen	,,	,,	7 17 5·4	+ 0 4·6
	8	I.	,, ,,	Full brightness	,,	,,	7 19 5·5	
	24	I.	,, ,,	First seen	,,	130	5 36 0·0	+ 0 49·2

Remarks.

March 28.—Definition of Satellite I. not good; observation probably somewhat late. IV. growing faint at $14^h\ 37^m\ 26^s$, and I thought I could just glimpse it again at $14^h\ 39^m\ 20^s{\cdot}8$. Satellite first noted at $16^h\ 28^m\ 4{\cdot}7^s$, but I was quite certain of it 57 seconds later.

April 1.—Fair definition; satellite suspected 32 seconds before recorded time.

April 4.—Clear, but definition bad and images tremulous.

April 22.—Good definition and observation.

April 24.—Beautifully clear and definition excellent; very good observation.

May 1.—Images steady and definition excellent; good observation.

May 8.—Images steady and definition good; beautifully clear. The observation of the first appearance of II. probably rather late.

May 14.—Beautifully clear and definition good.

May 15.—Good definition, but sky overspread with thin cloud.

May 21.—Beautifully clear. Definition very good at disappearance, but images rather tremulous at reappearance. Defalcation of light marked at $7^h\ 59^m\ 45^s{\cdot}9$. Satellite suspected a few seconds before recorded time of first appearance.

May 22.—Definition excellent throughout.

May 31.—Beautifully clear and definition good.

June 25.—Definition fair at ingress, but not so good at egress.

June 26.—Images steady, and definition unusually good.

June 27.—Beautifully clear, images steady and well defined; good observation.

June 29.—Bad definition.

July 3.—Definition excellent, with clear sky.

July 4.—Clear, but with bad definition.

July 10.—Fair definition.

July 11.—Clear; definition fair, but images tremulous.

July 28.—Definition not good enough for a higher power. Satellite barely visible as a light spot at $5^h\ 29^m\ 10^s$, and quite invisible at $5^h\ 53^m\ 36^s$. At $6^h\ 32^m\ 30^s$ pretty conspicuous as a dark, not black, hazy spot; it had then nearly reached mid-transit, and was rather more than half the planet's semi-diameter distant from the planet's centre. Clouds prevented further observation.

August 8.—Beautifully clear, but with poor definition. Satellite III. suspected 10 seconds before recorded time of first appearance. Image of I. tremulous, with bad definition.

August 24.—Beautifully clear, but twilight very strong. Sun's upper limb disappeared behind the horizon $6^m\ 53^s$ before the recorded time of reappearance. Image steady and definition good.

Windsor, N.S. Wales: 1886, *Sept.* 28.

Newall's Occulter. By R. S. Newall, F.R.S.

I lately designed, and had made by a clever local optician, an addition to the eyepiece of my telescope, which I find of the greatest advantage in examining the satellites of planets and multiple stars.

My idea was to produce an instrument exactly the reverse of Dawes's solar eyepiece; that is, to interpose a screen which shall shut off the bright object, and thus allow of the faint companions being more easily seen, and, at the same time, the

apparatus must be simple and capable of easy manipulation and adjustment.

I had my eyepieces each fitted with a *stop*, that is, a piece of tube the same diameter as the adapter, into which the eyepiece fits, and the stop is cut of such length that when the eyepiece is pushed in it shall be in the focus suited to my sight, so that I have no trouble in adjusting.

The occulter is a ring of brass, about a quarter of an inch thick and three-quarters broad. It slips stiffly on to the eye-piece as shown in the accompanying drawing. The ring is bored with three holes, as in the section, and into each is fitted an ivory sphere, three-eighths of an inch in diameter. They are held in place by brass springs, which have a quarter-inch hole in each, to admit of the movement in any direction of a small platinum wire, which passes through the sphere. On one end of the wire is a disc, and on the other a small button or handle.

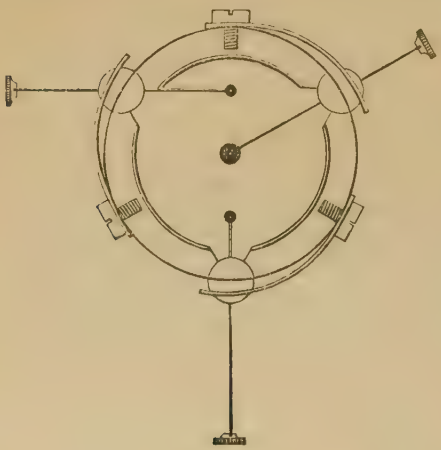


FIG. 1.

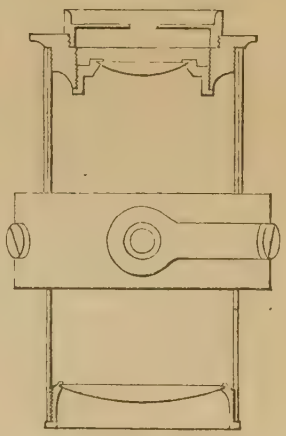


FIG. 2.

By these means the discs may be placed in any required position to eclipse the object, or they may be pushed to one side, so as to be entirely out of view; and when drawn back up to the ivory sphere the ring can be slipped off the tube, and the eyepiece is as it was, having only three holes in it corresponding to those in the ring. The centres of these holes are, of course, in the plane of the focus of the eye-lens, but the spheres allow of the discs being placed out of focus, which is sometimes of advantage. One disc would be quite enough for most work, but a spare one or two may be convenient occasionally, so I made mine with three discs slightly varying in size.

November 8, 1886.

Distribution of Meteor Streams. By W. F. Denning.

I recently compiled a general catalogue of all the meteor streams recorded in the various publications which I collected together for the purpose. These include the observations or reductions of Backhouse, Bártfay, Corder, Denning, Denza, Greg, Gruber, Herschel, Heis, Kobold, Konkoly, Kövesligethy, Maggi, Neumayer, Sawyer, Schiaparelli, Schmidt, Serpieri, Tupman, Weiss, Zezioli, and many other minor contributors.

Mr. Greg's last Catalogue of 1876 was based on 850 radiants deduced from 15,000 catalogued meteors. At the present time we have 3,035 radiants, derived from more than 82,000 meteors. There has been an enormous increase in these observations during the last ten years.

Upon analysing all the positions, I find they exhibit a very unequal distribution amongst the constellations, a fact which is unquestionably due, partly to real differences, and, in a less degree, to the relatively excessive observations accumulated in certain months of the year. In Right Ascension the 3,035 radiant points are situated as follows :

R.A.			Radiants.	Per-centage.	R.A.			Radiants.	Per-centage.
°		°			°		°		
1	to	30	378	12·4	181	to	210	147	4·8
31	„	60	449	14·8	211	„	240	186	6·1
61	„	90	315	10·3	241	„	270	217	7·2
91	„	120	229	7·6	271	„	300	254	8·4
121	„	150	192	6·3	301	„	330	243	8·0
151	„	180	142	4·7	331	„	0	283	9·3

The meteor streams cluster in greatest abundance between 1° and 60° of R.A. This is a fact irrespective of the cometary showers of Andromedes (Nov. 27) and Perseids (Aug. 10), which fall in this region, and might be supposed to have induced the singular condensation referred to. The zone, following it from 61° to 90°, shows a great decline, notwithstanding it includes the Orionids (Oct. 17–20), and the mass of showers originating in *Auriga*, *Camelopardus*, and the eastern quarter of *Taurus*. And the zone, 331° to 0° preceding the region of maximum, though rich in Aquariads, Pegasids, Lacertids, and Cepheids, exhibits a great deficiency as compared with it. The excess, so decided in character, between 1° and 60° is distinctly to be attributed to the Cassiopeids, α, β, and γ Andromedes, Arietids, Muscids, α and β Perseids, Taurids, &c., which, combined with the cometary showers of Andromedes and Perseids, swell the aggregate number to an abnormal figure.

The minimum proportion of showers is clearly indicated

between 151° and 210° R.A., which does not much exceed one-third of those grouped between 1° and 60°, the relative figures being 289 and 827.

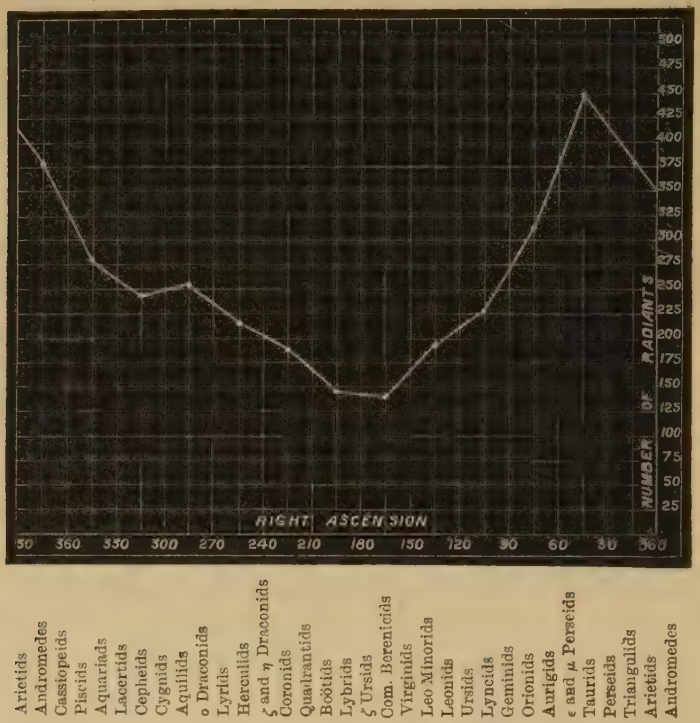


Fig. I.—Distribution of meteor streams in Right Ascension.

In North Polar Distance the showers are placed as follows:

N.P.D.			Radiants.	Percentage.	N.P.D.			Radiants.	Percentage.
°		°			°		°		
0	to	9	39	1·3	60	to	69	392	12·9
10	,,	19	141	4·7	70	,,	79	335	11·0
20	,,	29	243	8·0	80	,,	89	211	6·9
30	,,	39	473	15·6	90	,,	99	127	4·2
40	,,	49	489	16·1		+99		170	5·6
50	,,	59	415	13·7					

The maximum obviously lies between 30° and 49° N.P.D., and the minimum naturally occurs at the pole, inasmuch as the zone 0° to 9° includes a much smaller area than any other.

The distribution of the observed radiants in N.P.D. is

affected by the differences in the areas of the several zones and their relative degrees of visibility. Though towards the pole the total space included in the zones becomes less, yet this is in a large measure compensated for by their more favourable position and the persistency with which they are displayed to view. The entire zones, from 0° to 49° N.P.D., never fail below the horizon, and such showers as they present are therefore determinable at any period of the year or time of night. This applies specially to English latitudes, but it also has a general reference (with perhaps slight modification in certain instances) because nearly all our existing observations of shooting stars have been made at stations having considerable (*i.e.* exceeding 35°) north latitude. The summary proves that while the two zones embraced between the parallels of 30° and 49° N.P.D. have the largest number of recorded streams, the three zones succeeding towards the equator exhibit a gradual decline, though each remains fairly prolific. The Andromedes, Perseids, and Quadrantids are arranged between 30° and 49°, while the Geminids, Leonids, and Lyrids, are clustered between 50° and 69° N.P.D. Considering all the circumstances, there do not appear to be great inequalities of grouping in North Polar Distance similar to those which undoubtedly occur in Right Ascension, but the point requires further investigation.

In considering the distribution of meteor streams, several important conditions must not be lost sight of. The bulk of the observations have been effected in the summer months, whence it necessarily follows that such constellations as are most favourably visible at this period must certainly appear to exhibit a predominance of showers. I gave a summary in the *Monthly Notices*, vol. xxxix. p. 411, showing the comparative monthly numbers of meteors registered in twelve catalogues, and I have now added several others, the aggregate including 82,156 meteors, with the following result:

Month.	Meteors Catalogued.	Per-centage.	Month.	Meteors Catalogued.	Per-centage.
January	2804	3·4	July	10670	12·1
February	1826	2·2	August	31516	38·1
March	1764	2·1	September	4304	5·1
April	5585	6·8	October	6840	8·3
May	2120	2·6	November	8319	11·3
June	2353	2·9	December	4055	4·9

These numbers are derived from the catalogues of Corder, Denning, Denza, Heis, Konkoly, Lucas, Sawyer, Schmidt, Tupman, Weiss, Zezioli, and the Italian Meteoric Association, 1869, 1870, and 1872, and some minor lists.

Now, more than one-half the total number of observations were obtained in July and August, and, in point of fact, are

nearly all embraced between the period from July 20 to August 15. The majority of the observations have been secured before midnight, and it is therefore certain that the region of 31° to 60° R.A., which is for the most part either below the horizon or low in the north-east at the special epoch when the largest number of meteors have been recorded, is not rendered rich solely by the abundance of observations. Indeed the months of September, October, and November appear to have furnished, relatively to the number of meteors catalogued, by far the greatest number of showers in this quarter of the sky. I

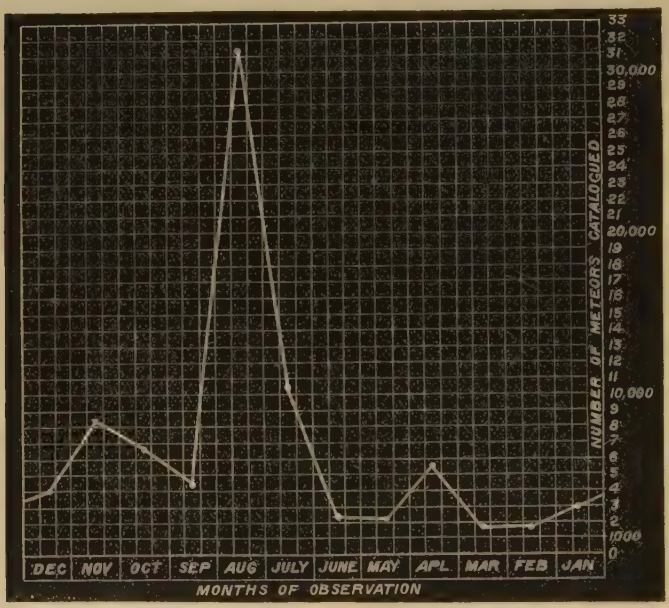


Fig. II.—Relative numbers of meteors catalogued during the twelve months.

believe, therefore, the great superabundance of streams about *Andromeda*, *Aries*, and *Perseus* is a real one.

We must remember that the large proportion of meteors catalogued in July, August, and later months is far from being entirely due to the more extensive watches undertaken at those times. It is attributable in a great measure to a real surplus in the visible number of meteors. All regular workers in this department agree as to the far greater frequency of meteors during the last half of the year as compared with the first half. From my own observations, up to the end of 1885, comprising 7,100 meteors, I find that the average horary number for one observer from January to June is 6·95, and from July to

December 12·65, so that the excess in favour of the last half of the year is nearly in the proportion of 2 to 1. From this we may conclude that both meteors and meteoric radiants display by far the greatest profusion between July and December, and that the densest region of radiation lies between 1° and 60° of R.A. This is indeed the most active part of the heavens even as late as November, when it is some 110° distant from the apex of the Earth's way.

The known meteor streams, considered in respect to their apparent distribution upon the celestial vault, exhibit special regions of density and scarcity, not exactly regulated by the direction of the Earth's motion. The maximum number of showers is rarely seen in that part of the firmament towards which the Earth is directed, though with a perfectly equal distribution of streams this would be expected. The richest showers usually come from positions far to the west of the Earth's apex, and this is sufficient evidence that they exhibit a special construction or grouping together. The Earth becomes alternately involved with rich and tenuous regions at intervals of about six months.

Bristol: 1886. *November* 9.

Ephemeris for Physical Observations

Greenwich Noon.	Angle of Position of ♃'s Axis.	Latitude of Earth above ♃'s Equator	Latitude of Sun above ♃'s Equator	Annual Parallax.		Longitude of ♃'s Central Meridian. (878°·25)	(870°·27)	Corr. for Phase.
	P	B	*B*	A−L.	L−O.	I	II	
1886	°	°	°	°	°	°	°	
Dec. 9	22·064	−2·862	−2·796	−7·799	73·435	34·15	251·43	+0·264
14	21·877	2·893	2·804	8·282	74·297	104·86	282·24	·298
19	21·694	2·923	2·813	8·726	75·119	175·62	313·10	·331
24	21·516	2·952	2·821	9·127	75·898	246·45	344·02	·362
29	21·345	2·980	2·829	9·481	76·630	317·34	15·00	·390
1887								
Jan. 3	21·182	−3·008	−2·836	−9·784	77·311	28·29	46·05	+0·415
8	21·030	3·036	2·844	10·032	77·937	99·30	77·16	·437
13	20·890	3·063	2·852	10·222	78·505	170·38	108·34	·444
18	20·763	3·089	2·859	10·351	79·012	241·53	139·59	·465
23	20·651	3·114	2·866	10·414	79·454	312·75	170·90	·471
28	20·555	3·139	2·874	10·409	79·827	24·04	202·28	·470
Feb. 2	20·476	3·162	−2·881	−10·332	80·128	95·40	233·73	+0·463
7	20·416	3·185	2·888	10·181	80·356	166·83	265·26	·450
12	20·376	3·206	2·894	9·954	80·508	238·32	296·85	·430
17	20·355	3·225	2·901	9·649	80·582	309·88	328·51	·404
22	20·355	3·242	2·908	9·265	80·577	21·51	0·23	·372
27	20·375	3·258	2·914	8·802	80·492	93·20	32·02	·336
Mar. 4	20·416	−3·271	−2·920	−8·261	80·329	164·95	63·86	+0·296
9	20·476	3·282	2·927	7·644	80·092	236·75	95·76	·254
14	20·554	3·290	2·933	6·954	79·782	308·60	127·71	·210
19	20·650	3·295	2·939	6·196	79·403	20·49	159·70	·167
24	20·761	3·297	2·944	5·375	78·961	92·41	191·72	·126
29	20·884	3·296	2·950	4·497	78·462	164·35	223·76	·088
Apr. 3	21·017	−3·292	−2·956	−3·571	77·915	236·31	255·82	+0·056
8	21·158	3·285	2·961	2 607	77·330	308·28	287·88	·030
13	21·303	3·274	2·966	1·614	76·716	20·23	319·93	·011
18	21·451	3·260	2·971	−0·602	76·084	92·16	351·97	+0·002
23	21·598	3·243	2·976	+0·418	75·444	164·07	23·97	−0·001
28	21·741	3·223	2·981	1·434	74·808	235·93	55·93	·009
May 3	21·879	−3·201	−2·986	+2·434	74·188	307·74	87·84	−0·026
8	22·009	3·177	2·991	3·408	73·594	19·48	119 68	·051
13	22·129	3·151	2·995	4·347	73·035	91·15	151·46	·082
18	22·238	3·124	3·000	5·242	72·520	162·74	183·16	·119
23	22·335	3·096	3·004	6·085	72·058	234·25	214·77	·161

of Jupiter 1887. By A. Marth.

Greenwich Noon		Diameter Equat.	Diameter Polar.	Difference of limbs in A. R.	Difference of limbs in Decl.	Defect of illumination. Equat. preceding limb	Defect of illumination. in A. R.	Defect of illumination. in Decl. north *l.*	*d*	*w*
1886		"	"	s	"	"	s	"	°	°
Dec.	9	32·32	30·26	2·168	30·56	0·15	0·009	0·02	7·79	269 69
	14	32·66	30·58	2·193	30·88	·17	·010	·02	8·27	269·57
	19	33·02	30·93	2·220	31·22	·19	·011	·03	8·71	269·46
	24	33·42	31·30	2·249	31·59	·21	·013	·03	9 11	269·37
	29	33·84	31·69	2·280	31·98	·23	·014	·03	9·47	269·28
1887										
Jan.	3	34·29	32·11	2·312	32·40	0·25	0·015	0 03	9·77	269·19
	8	34·76	32·55	2·346	32·84	·27	·016	·03	10·02	269·11
	13	35·26	33·01	2·381	33·31	·28	·017	·03	10·21	269·02
	18	35·77	33·50	2·417	33·79	·29	·018	·03	10·34	268 93
	23	36·31	34·01	2·455	34·30	·30	·018	·04	10·40	268·84
	28	36·87	34·53	2·494	34·82	·30	·018	·04	10·40	268·74
Feb.	2	37·44	35·06	2·533	35·36	0·30	0·018	0·03	10·32	268 63
	7	38·02	35·60	2·573	35·91	·30	·018	·03	10·17	268 51
	12	38·60	36·15	2·614	36 46	·29	·018	·03	9·94	268·37
	17	39·19	36·71	2·654	37·02	·28	·017	·03	9 64	268 23
	22	39·78	37·26	2·693	37 57	·26	·016	·03	9·26	268·06
	27	40·36	37·80	2·732	38 12	·24	·015	·02	8·80	267·86
Mar.	4	40·92	38·33	2·769	38·65	0·21	0·014	0·02	8·26	267·64
	9	41·46	38·83	2·804	39·16	·18	·012	·02	7·64	267·38
	14	41·97	39·30	2·837	39·64	·15	·010	·02	6·95	267·06
	19	42·44	39·74	2·867	40·09	·12	·008	·01	6·20	266·67
	24	42·86	40·14	2·894	40·49	·09	·006	·01	5·38	266·14
	29	43·23	40·49	2·917	40·84	·07	·004	·01	4·51	265·43
Apr.	3	43·54	40·78	2·935	41·14	0·04	0·003	0·00	3·60	264·35
	8	43·78	41·01	2·949	41·38	·02	·001	—	2·63	262·5
	13	43·96	41·17	2·959	41·55	·01	·001	—	1·64	258·7
	18	44·06	41·26	2 964	41·65	on following limb		on south limb	0·68	242·8
	23	44·09	41·29	2·963	41·68				0·52	123·4
	28	44·04	41·24	2·957	41·64	0·01	0·000	0·00	1·47	102·7
May	3	43·91	41·12	2·946	41·53	·02	·001	·00	2·44	95·3
	8	43·72	40·94	2·931	41·35	·04	·002	·01	3·41	93·24
	13	43·46	40·70	2·911	41·10	·06	·004	·01	4·34	92·07
	18	43·14	40·40	2·888	40·80	·09	·005	·02	5·24	91·30
	23	42 76	40·05	2·862	40·45	·12	·007	·02	6·08	90·76

Greenwich Noon	Angle of Position of ♃'s Axis.	Latitude of Earth above ♃'s Equator.	Latitude of Sun above ♃'s Equator.	Annual Parallax.		Longitude of ♃'s Central Meridian. (878°·25)	(870°·27)	Corr. for Phase.
	P	B	*B*	A−L.	L−O.	I	II	
1887	°	°	°	°	°	°	°	°
May 28	22·418	3·068	3·008	6·868	71·655	305·67	246·29	·205
June 2	22·487	−3·040	−3·012	+7·586	71·317	17 00	277·72	−0·250
7	32·542	3·013	3·016	8·236	71·047	88·24	309·06	·294
12	22·582	2·987	3·020	8·814	70·849	159·38	340·30	·337
17	22·608	2·961	3·023	9·318	70·726	230·42	11·45	·377
22	22·619	2·937	3·027	9·747	70·678	301·37	42·50	·412
27	22·615	2·915	3·030	10·101	70·705	12·24	73·47	·443
July 2	22·567	−2·895	−3·033	+10·380	70·806	83·02	104·35	−0·467
7	22·564	2·876	3·036	10·586	70·981	153·71	135·15	·486
12	22·516	2·859	3·039	10·721	71·227	224·33	165·87	·498
17	22·454	2·845	3·042	10·787	71·542	294·88	196 52	·505
22	22·378	2 833	3·045	10·786	71·925	5·36	227·10	·505
27	22·288	2·823	3·047	10·720	72·372	75·77	257·62	·498
Aug. 1	22·183	−2·815	−3·050	+10·594	72·880	146·13	288·08	−0·486
6	22·064	2·809	3·052	10·411	73·445	216·43	318·49	·470
11	21·931	2·804	3·054	10·173	74·065	286·69	348·85	·449
16	21·785	2·801	3·056	9·882	74 737	356 90	19·17	·424
21	21·624	2·800	3·058	9·543	75·458	67·08	49·45	·395
26	21·450	2·800	3·060	9·159	76·225	137·23	79·70	·364
31	21·261	2·801	3·061	8·732	77·034	207·35	109·02	·331
Sept. 5	21·059	−2·805	−3·063	+8·266	77·883	277·44	140·11	−0·297

The angle A−L is the difference of the Jovicentric longitudes of the Sun and Earth, reckoned in the plane of *Jupiter's* equator L−O+180° the Jovicentric longitude of the Earth reckoned from O, the point of *Jupiter's* vernal equinox or the point of the ascending node of the planet's orbit on its equator. Two values of the "longitude of ♃'s central meridian" are given for each date, the first, computed with the daily rate of rotation 878°·25, being intended for comparing the observations of the white spots in the neighbourhood of the planet's equator; the second, computed with the rate 870°·27, for the observations of the remnant of the great reddish spot in the planet's southern hemisphere. The apparent irregularities in the motion of the white equatorial spots leave it doubtful whether the adopted slackened rate of rotation will be approximately correct during the approaching apparition of *Jupiter*. But observers who have instrumental and climatic opportunities for observing the spots assiduously can, after the first observations, easily make allowance for any changes of the positions of the spots in reference to the system I. of longitudes. If the slackening of the motion of the great

Greenwich Noon	Diameter Equat.	Diameter Polar.	Difference of limbs in A. R.	Difference of limbs in Decl.	Defect of illumination. Equat. following limb	Defect of illumination. in A. R.	Defect of illumination. in Decl. south *l.*	*d*	*w*
1887	″	″	s	″	″	s	″	°	°
May 28	42·33	39·65	2·832	40·05	0·15	0·009	0·02	6·86	90·34
June 2	41·87	39·21	2·800	39·61	0·18	0·011	0·03	7·57	90·02
7	41·37	38·74	2·766	39·14	·21	·012	·03	8·22	89·75
12	40·84	38·25	2·731	38·64	·24	·014	·04	8·80	89·52
17	40·30	37·74	2·694	38·13	·27	·016	·04	9·30	89·33
22	39·74	37·22	2·657	37·60	·29	·017	·04	9·73	89·17
27	39·18	36·69	2·619	37·07	·30	·018	·04	10·09	89·02
July 2	38·61	36·16	2·582	36·53	0·31	0·018	0·04	10.37	88·89
7	38·05	35·63	2·545	36·00	·32	·019	·05	10·57	88·78
12	37·49	35·11	2·509	35·47	·33	·019	·05	10·71	88·68
17	36·95	34·60	2·473	34·95	·33	·019	·04	10·77	88·59
22	36·42	34·10	2·439	34·45	·32	·019	·04	10·77	88·50
27	35·91	33·62	2·406	33·96	·31	·019	·04	10·71	88·43
Aug. 1	35·41	33 16	2·374	33·49	0 30	0 018	0·04	10·58	88·36
6	34·94	32·72	2·344	33·04	·29	·017	·04	10·40	88·29
11	34·48	32 29	2·316	32·61	·27	·016	·03	10·16	88·22
16	34·05	31 89	2·289	32·20	·25	·015	·03	9·87	88·15
21	33·65	31·51	2·264	31·81	·23	·014	·03	9·53	88·08
26	33 26	31·15	2·241	31·44	·21	·013	·03	9·15	88·01
31	32 91	30·81	2·219	31·10	·19	·012	·02	9·72	87·94
Sept. 5	32·57	30·50	2·199	30·78	0·17	0·010	0·02	9·26	87·87

reddish spot should be maintained, its place will be found near the zero meridian of the system II. of longitudes. The periods of rotation corresponding to the adopted rates are

		h	m	s
I. daily rate 878°·25	period	9	50	15·88
II. 870°·27		9	55	40·63

The differences of successive values in the two columns for "Longitude, &c.," amount for the intervals of five days to 12 rotations in addition to the differences directly deduced, so that, for instance, the differences of the values for Dec. 14 and Dec. 9 are 4390°·71 and 4350°·81. The addition of the correction for phase "to the longitude of ♃'s central meridian" gives the longitude of the meridian which bisects the illuminated disc. A list of Greenwich times when their longitude is 0° will be found further on.

The diameters of the disc, etc., depend on the same assumed values as in the ephemeris for the preceding apparition. The formulæ employed may be found in vol. xlv. p. 508.

The inclinations γ and the ascending nodes Γ of the orbits of the four satellites of *Jupiter* in reference to the plane of the planet's equator are the following, the longitudes of the nodes being reckoned from O, the point of the ascending node of *Jupiter's* orbit on the equator:

1886.	Sat. I. γ_1	Sat. I. Γ_1	Sat. II. γ_2	Sat. II. Γ_2	Sat. III. γ_3	Sat. III. Γ_3	Sat. IV. γ_4	Sat. IV. Γ_4
	°	°	°	°	°	°	°	°
Nov. 9	0·0118	295·6	0·4923	294·06	0·1476	250·93	0·3206	330·40
1887.								
Jan. 8	·0117	294·3	·4925	292·17	·1466	250·67	·3206	330·51
Mar. 9	·0117	292·9	·4927	290·28	·1455	250·40	·3205	330·62
May 8	·0116	291·5	·4928	288·39	·1444	250·11	·3203	330·74
July 7	·0116	290·1	·4928	286·50	·1433	249·81	·3200	330·86
Sept. 5	·0115	288·6	·4928	284·60	·1422	249·49	·3196	330 98
Nov. 4	0·0114	287·0	0·4928	282 69	0·1411	249·15	0·3191	331 09

Has the eclipse of Sat. IV. on May 17, 1886, which was not given by the Tables, but the probable occurrence of which was mentioned in vol. xlv. p. 509, not been observed anywhere?

The following is a list of Greenwich mean times, when the zero meridian in the assumed two systems of longitudes will pass the middle of the illuminated disc. To save printing, the time of only one passage is given for each day, and the others must be found by interpolation, or, if greater accuracy is not required, by adding or subtracting $9^h\ 50^m$ in the first system, and $9^h\ 56^m$ in the second.

1886	I (878°·25) h m	II (870°·27) h m	1886	I (878°·25) h m	II (870°·27) h m
Dec. 9	18 44·2	12 55·0	Dec. 25	18 26·8	16 8·8
10	14 24·9	18 42·2	26	14 7·5	12 0 2
11	19 55·9	14 33·7	27	19 38·4	17 47·4
12	15 36·6	20 21·0	28	15 19·0	13 38·8
13	21 7·6	16 12·5	29	20 49·9	19 26·0
14	16 48·2	12 3·9	30	16 30 5	15 17·4
15	12 28·9	17 51·2	31	12 11·1	21 4·5
16	17 59·8	13 42·6	1887		
17	13 40·5	19 29·9	Jan. 1	17 42 0	16 56·0
18	19 11·5	15 21·3	2	13 22·6	12 47·4
19	14 52·1	21 8·5	3	18 53·5	18 34·5
20	20 23·1	17 0·0	4	14 34·1	14 26·0
21	16 3·7	12 51·5	5	20 5·0	20 13·1
22	21 34·7	18 38·7	6	15 45·6	16 4·5
23	17 15·3	14 30·1	7	11 26·2	11 55 9
24	12 55·9	20 17·3	8	16 57·0	17 43·0

1887	I (878°·25) h m	II (870°·27) h m
Jan. 9	12 37·6	13 34·4
10	18 8·5	19 21·5
11	13 49·0	15 12·9
12	19 19·9	11 4·3
13	15 0·4	16 51·4
14	10 41·0	12 42 8
15	16 11·8	18 29·8
16	10h·5 conj. of ♃ with	
	✶ 8m W.B. 14, 111	
	✶ 0′2 north of limb.	
—	11 52·4	14 21·2
17	17 23·2	10 12·6
18	13 3·7	15 59·6
19	18 34·6	11 51·0
20	14 15·1	17 38·0
21	19 45·9	13 29·4
22	15 26·4	19 16·4
23	11 7·0	15 7·8
24	16 37·7	10 59·1
25	12 18·3	16 46·2
26	17 49·0	12 37·5
27	13 29·6	18 24·5
28	19 0·3	14 15·9
29	14 40·8	20 2·9
30	20 11·6	15 54·2
31	15 52·1	11 45·5
Feb. 1	11 32·6	17 32·5
2	17 3·3	13 23·8
3	12 43·8	19 10·8
4	18 14·5	15 2·1
5	13 55·0	10 53·4
6	19 25·8	16 40·4
7	15 6 2	12 31·7
8	10 46·7	18 18·6
9	16 17·4	14 9·9
10	11 57·9	10 1·2
11	17 28·6	15 48·1
12	13 9·0	11 39·4

1887	I (878°·25) h m	II (870°·27) h m
Feb. 13	18 39·7	17 26·3
14	14 20·2	13 17·6
15	10 0·6	19 4·5
16	15 31·3	14 55·8
17	11 11·7	10 47 1
18	16 42 4	16 34·0
19	12 22·8	12 25·4
20	17 53·5	18 12·1
21	13 33·9	14 3·4
22	19 4·6	19 50·3
23	14 45·0	15 41·5
24	10 25·4	11 32·7
25	15 56·0	17 19·6
26	11 36·5	13 10·8
27	17 7·1	18 57·7
28	12 47·5	14 48·9
March 1	18 18·1	10 40·2
2	13 58·5	16 27·0
3	9 38·9	12 18·2
4	15 9·5	18 5·1
5	10 49·9	13 56·3
6	16 20·5	9 47·5
7	12 0·9	15 34·3
8	17 31·5	11 25·5
9	13 11·8	17 12·3
10	8 52·2	13 3 6
11	14 22·8	8 54·8
12	10 3 2	14 41 6
13	15 33·7	10 32·8
14	11 14·1	16 19·6
15	16 44·7	12 10 8
16	12 25·0	8 1·9
17	8 5·4	13 48·7
18	13 36·0	9 39·9
19	9 16·3	15 26·7
20	14 46·9	11 17·9
21	10 27·2	17 4·7
22	15 57·8	12 55 8

1887	I (878°·25) h m	II (870°·27) h m	1887	I (878°·25) h m	II (870°·27) h m
March 23	11 38·1	8 47·0	April 30	14 24·6	10 1·1
24	17 8·7	14 33·8	May 1	10 4·9	5 52·3
25	12 49·0	10 25·0	2	5 45·3	11 39·1
26	8 29·4	16 11·7	3	11 15·9	7 30·3
27	13 59·9	12 2·9	4	6 56·3	13 17·2
28	9 40·2	7 54·1	5	12 26·9	9 8·4
29	15 10·8	13 40·8	6	8 7·3	14 55·2
30	10 51·1	9 32·0	7	13 37·9	10 46·5
31	16 21·6	15 18·8	8	9 18·3	6 37·7
April 1	12 2·0	11 9·9	9	14 49·0	12 24·5
2	7 42·3	7 1·1	10	10 29·4	8 15·8
3	13 12·8	12 47·9	11	6 9·8	14 2·7
4	8 53·2	8 39·0	12	11 40·5	9 53·9
5	14 23·7	14 25·8	13	7 20·9	5 45·2
6	10 4·0	10 16·9	14	12 51·6	11 32·1
7	15 34·6	6 8·1	15	8 32·0	7 23·3
8	11 14·9	11 54·8	16	14 2·7	13 10·2
9	6 55·3	7 46·0	17	9 43·1	9 1·5
10	12 25·8	13 32·8	18	5 23·6	14 48·4
11	8 6·1	9 23·9	19	10 54·3	10 39·7
12	13 36·6	15 10·7	20	6 34·8	6 31·0
13	9 17·0	11 1·9	21	12 5·5	12 18·0
14	14 47·5	6 53·0	22	7 46·0	8 9·3
15	10 27·9	12 39·8	23	13 16·7	13 56·2
16	6 8·2	8 30·9	24	8 57·2	9 47·5
17	11 38·7	14 17·7	25	14 27·9	5 38·8
18	7 19·1	10 8·9	26	10 8·4	11 25·8
19	12 49·6	6 0·0	27	5 48·9	7 17·2
20	8 30·0	11 46·8	28	11 19·7	13 4·2
21	14 0·5	7 38·0	29	7 0·2	8 5·5
22	9 40·8	13 24·7	30	12 30·9	14 42·5
23	15 11·4	9 15·9	31	8 11·5	10 33·8
24	10 51·7	15 2·7	June 1	13 42·3	6 25·2
25	6 32·1	10 53·9	2	9 22·8	12 12·2
26	12 2·7	6 45·1	3	5 3·3	8 3·6
27	7 43·0	12 31·9	4	10 34·1	13 50·7
28	13 13·6	8 23·1	5	6 14·7	9 42·0
29	8 54·0	14 9·9	6	11 45·5	5 33·4

1887	I (878°·25) h m	II (870°·27) h m
June 7	7 26·1	11 20·5
8	12 56·9	7 11·9
9	8 37·5	12 59·0
10	14 8·4	8 50·3
11	9 48·9	14 37·4
12	5 29·5	10 28·9
13	11 0·4	6 20·3
14	6 41·0	12 7·4
15	12 11·9	7 58·8
16	7 52·5	13 46·0
17	13 23·4	9 37·4
18	9 4·0	5 28·8
19	14 34·9	11 16·0
20	10 15·6	7 7·4
21	5 56·2	12 54·6
22	11 27·1	8 46·1
23	7 7·8	14 33·3
24	12 38·7	10 24·7
25	8 19·4	6 16·2
26	13 50·3	12 3·4
27	9 31·0	7 54·9
28	5 11·6	13 42·1
29	10 42·6	9 33·6
30	6 23·3	5 25·1
July 1	11 54·3	11 12·3
2	7 35·0	7 3·8
3	13 6·0	12 51·1
4	8 46·7	8 42·6
5	14 17·7	14 29·9
6	9 58·4	10 21·4
7	5 39·1	6 12·9
8	11 10·1	12 0·2
9	6 50·8	7 51·7
10	12 21·9	13 39·0
11	8 2·6	9 30·5
12	13 33·6	5 22·1
13	9 14·4	11 9·4
14	4 55·1	7 0·9

1887	I (878°·25) h m	II (870°·27) h m
July 15	10 26·2	12 48·3
16	6 6·9	8 39·8
17	11 38·0	4 31·4
18	7 18·7	10 18·7
19	12 49·8	6 10·3
20	8 30·6	11 57·6
21	4 11·3	7 49·2
22	9 42·4	13 36·6
23	5 23·2	9 28·1
24	10 54·3	5 19·7
25	6 35·0	11 7·1
26	12 6·2	6 58·7
27	7 46·9	12 46·0
28	13 18·1	8 37·6
29	8 58·8	4 29·2
30	4 39·6	10 16·6
31	10 10·8	6 8·2
Aug. 1	5 51·5	11 55·6
2	11 22·7	7 47·2
3	7 3·5	3 38·8
4	12 34·7	9 26·2
5	8 15·4	5 17·9
6	3 56·2	11 5·3
7	9 27·4	6 56·9
8	5 8·2	12 44·3
9	10 39·4	8 35·9
10	6 20·2	4 27·6
11	11 51·4	10 15·0
12	7 32·2	6 6·4
13	13 3·4	11 54·1
14	8 44·2	7 45·7
15	4 25·0	3 37·3
16	9 56·2	9 24·3
17	5 37·0	5 16·4
18	11 8·2	11 3·9
19	6 49·0	6 55·5
20	12 20·2	12 43·0
21	8 1·0	8 34·6

1887	I (878°·25) h m	II (870°·27) h m	1887	I (878°25). h m	II (870°27) h m
Aug. 22	3 41·9	4 26·3	Aug. 29	12 49·3	5 15·3
23	9 13·1	10 13·7	30	8 30·1	11 2·8
24	4 53·9	6 5·4	31	4 10·9	6 54·4
25	10 25·1	11 52·9	Sept. 1	9 42·1	12 41·9
26	6 6·0	7 44·5	2	5 23·0	8 33·6
27	11 37·2	3 36·2	3	10 54·2	4 25 3
28	7 18·0	9 23·7	4	6 35·1	10 12·7